

BUILD THE FUTURE FOR SCIENCE

MARCH/APRIL 2016

PLUS!

RETURN TO
FUKUSHIMA

TERROR ON
TWITTER

HUNT FOR
PLANET X

THE VIZZIE
AWARDS

360°
CAMERAS

PRESIDENT OBAMA

ON SPACE,
STARTUPS,
AND WHY
NERDS
WILL
RULE
THE
WORLD

PG. 40

★
EXCLUSIVE
INTERVIEW
★



Yup, that's a Fitbit on
the president's wrist.



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FOREVER?**

SCIENCE TAKES
ON AGING

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MARCH/APRIL

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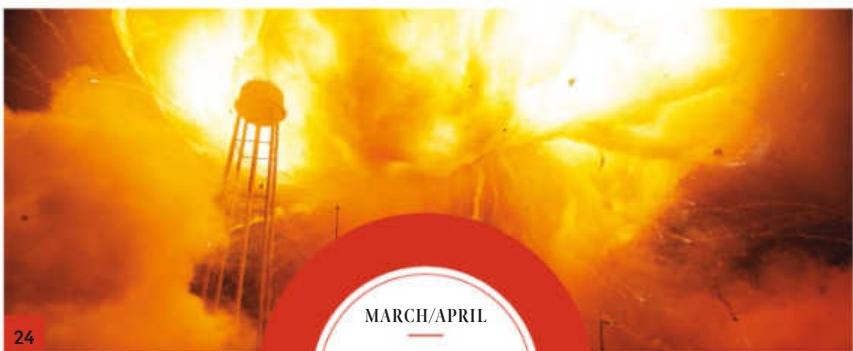
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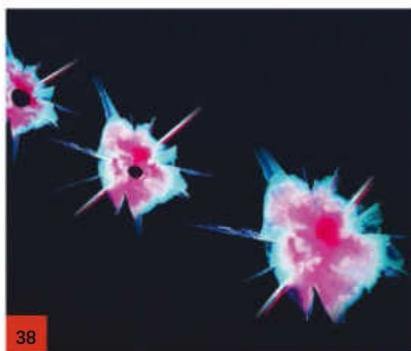
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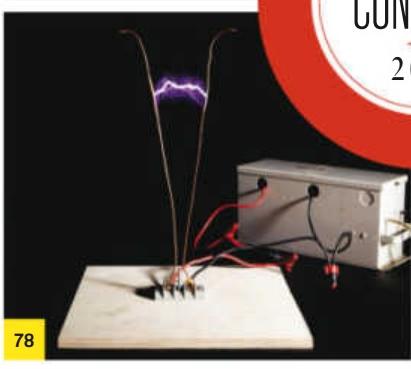
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AND THE DAY YOU FINALLY WALKED AWAY
AND THE TERROR OF OPENING A SMALL BUSINESS
AND THE FIRST QUARTERLY PROFIT YOU REINVESTED
AND LOVING MONDAY MORNINGS BECAUSE YOU'RE FREE



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Create Your Future

In technology and startup circles, there's a saying people like to toss around: "The best way to predict the future is to create it." No one really knows who said it first. Some people attribute it to Abraham Lincoln, others to the business guru Peter Drucker. But that doesn't stop it from showing up on mugs and T-shirts and in cheesy Keynote presentations.

As an editor, my tolerance for campy, prepackaged one-liners is more or less zero. It's as if two pieces of Styrofoam are rubbing together when I hear them. But at the risk of sounding clichéd, I kind of love this quote. I love its spirit. The future, it says, doesn't have to arrive by chance. We can purpose-build it to our needs.

The advice applies to individuals. You know, plan for retirement, avoid cliff diving, and slow down on those Baconator burgers. But it also applies to nations. If we want America to lead the world tomorrow, we need to make strategic bets today—and a number of those bets should be made in science and technology. Few fields shape our future as they do.

Many smart people help guide the national science and technology agenda, but one individual has an outsized impact: the president of the United States. Advised by some very brainy folks in the White House Office of Science and Technology Policy, the president determines what we, as a nation, should pursue. That could be neuroscience or clean energy or science education or some combination thereof. Those policy initiatives help drive funding that funding drives research and development; and that R&D lays the foundation for the future.

If you want to understand—at



the highest level—where science and technology are going, you ask the guy in charge. So we did. And President Barack Obama gave us one heck of an answer. He took us through all he's accomplished in the past seven years and all that remains for his final year in office. He covered private space, maker culture, climate change, the virtues of being a nerd, and the hazards of getting stranded on Mars. He talked about keeping America competitive and keeping the planet safe.

In today's political climate, it can be hard to find topics that don't inspire angst in one group or another. But in science and technology, we can usually find some common ground. At the magazine, our position has always been blissfully apolitical: If you stand with science, we stand with you. And whether we're talking to CEOs, scientists, or even the president of the United States, our questions are basically the same: Do you support good, unbiased research, and do you strive for big solutions to big problems? If so, let's talk.

During the State of the Union address in January, President Obama said, "We live in a time of extraordinary change—change that's reshaping the way we live, the way we work, our planet, and our place in the world." As readers of *Popular Science*, this likely isn't news to you. Change is one of the few constants in the universe. It's how we confront change that matters. The president can certainly help by setting the right science and technology agenda, and our magazine can help by making that agenda plain. But in the end, we all need to do more than dream of a brighter future. We need to get out there and build it.

Enjoy the issue.

Cliff Ransom
Editor in Chief

Editor in Chief Cliff Ransom
Design Director Todd Detwiler
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Before We Begin

Popular Science

FOUNDED MONTHLY 1872

FROM THE ARCHIVES

DECEMBER An amazing new motor-hoop of the speedway 25 CENTS

Thrilling escapes of a lion-hunter (See p. 38)

RADIO SECTION PAGE 76

Confessions of a radio "Gyp"—How to build a two-tube reflex set.

A "Radio Doctor" tells you how to get the most from your outfit.

FRED CRAFT

The Motor-Hoop of the Italian Speedway

DECEMBER 1924

Ninety-two years ago, Popular Science featured a "strange vehicle" that whirled around the speedway in a motorcycle race before the National Stadium in Rome. Spectators "gasped with amazement...when they saw a huge wheel, driven by a motorcycle engine, careening at high speed around the track like an overgrown toy hoop." The policeman who invented the motor-hoop had hidden it from Milan to Rome on a bet. Though he believed its potential for speed and utility were "almost limitless," the motor-hoop disappeared from our pages—and the world's roads—never to be seen again.

Science, Visualized



On page 66, we feature the winners of the 2016 Vizzies, a contest that challenges readers to visualize a scientific idea, concept, or story in an arresting way. Go to popsci.com/vizzies to see all of the finalists, including the video- and interactive-category winners.



Mad About Food

Social-media editor Jason Lederman recently dropped in to see what famed Food Network personality Alton Brown had cooked up at his food-science studio. Brown showed off a few of his inventions, including a machine that can freeze ice cream in 10 seconds, and a giant Easy-Bake-like oven that uses stage lights to cook pizza at 800 degrees. Stay tuned to popsci.com to see his creations in action.

That's a strange-looking Xbox controller...

We were so excited to get our inaugural double issue out on shelves that we made a few slip-ups. On page 13 of January/February 2016, we mixed up the labels on an Xbox wireless controller and a Slingbox M2 media box. On page 63, we called Fred Ehrsam the CFO of the Bitcoin wallet Coinbase, when he is actually the co-founder and president. And on page 90, we stated that the Potomac River was near the Aberdeen Proving Ground in northern Maryland. The river actually borders southern Maryland.



Want more? Check us out on social media! Besides Facebook, Twitter, Pinterest, and Instagram, look for our icon—a chimp in a spacesuit—on Tumblr and List App. You can even watch us test gear, fly drones, and conduct experiments (sometimes on each other) on Periscope.

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PIXEL-PERFECTION A NEW BREED OF TELEVISION

LG has created a brand new category of TV with the introduction of OLED and its emissive technology, **Organic Light Emitting Diodes**. These organic substances are self lighting and glow when an electric current runs through them. This innovation allows for each sub pixel to be individually lit and turned off or on as needed to create an ideal viewing experience.



INTENSE BLACK LEVELS:
by individually lighting
each pixel and being able
to turn them off, OLED
produces perfect black
levels resulting in
infinite contrast.

PIXELS POWERED
OFF CREATING
PERFECT BLACK

BRIGHT VIVID COLORS:
colors are more brilliant against a perfect black background.
Choose from Full HD or 4K screen resolutions.

EXTREMELY WIDE VIEWING ANGLE:
The exceptional picture quality holds up even from wide
viewing angles, so don't be afraid to load up the couch.

IMPOSSIBLY THIN DESIGN:
OLED technology enables a design that is ultra-thin and light. It's
supremely elegant, and as lovely on a tabletop as it is wall-mounted.
Available in both flat and curved models.

LG OLED TV
Experts Say It's The
BEST. PICTURE. EVER.

#OLEDisHere

EDITED BY MICHAEL NUÑEZ + XAVIER HARDING

MARCH/APRIL 2016



6 WAYS TO PLAY

Without Getting
Your Hands Dirty

We're calling it: We live in a golden age of remote-controlled gadgets. Technological leaps in sensors, batteries, processors, and motors. Of all the vehicles you can operate from a distance, here are six of the best—by air, by sea, and by land.

by
**DAVE
GERSHGORN**

TAKE FLIGHT

①

**YUNEEC TYPHOON
Q500 4K DRONE**
\$1,199.99

Who cares about federal drone regulations? The Typhoon Q500 always knows where it is and will stay within legal airspace (under 400 feet). It shoots 4K video and streams live to the controller's monitor (so you don't have to use your phone's spotty Wi-Fi connection). You can also remove the camera and attach it to a handheld gimbal for stabilized ground video.



DIVE DEEP

2

PARROT ORAK HYDROFOIL DRONE \$159

The Orak is a hybrid drone that's just as capable in the air as it is in the water. This hydrofoil is powered by a tiny quadcopter that lifts vertically about 3 inches from the hull to provide thrust. It can cruise past 6 mph atop the waves or up to 11 mph in the sky. Just detach the quadcopter and fly!

2

VideoRay

3
VIDEORAY
PRO 4
\$43,500

If you want to go deep (underwater and into your pockets), the VideoRay Pro 4 will take you there. This underwater drone has a maximum depth of 1,000 feet. The Pro 4 shoots video at 1080p and instantly transmits raw footage to the surface through its tether. It's also outfitted with two LED light arrays to illuminate your path through the ocean's depths.

4

OPENROV TRIDENT
\$1,199

OpenROV's Trident is an open-source submersible that can be piloted using a virtual-reality headset or a laptop, allowing you a full range of control up to 328 feet below the surface. The drone offers two hours of what the company calls "flight time." It also comes with a tether, so you can survey the deep ocean à la James Cameron without worrying about losing your precious explorer.

DRIVE HARD

5

ANKI OVERDRIVE
\$149.99

The raceway comes to your living room with this pair of futuristic vehicles. Build one of eight pre-configured tracks, then drive the cars using any Bluetooth-ready tablet or phone. Each car is programmed to race on its own, so you always have a worthy opponent.

6

TRAXXAS X-MAXX
\$799

Rip through any terrain with a monster truck the size (and demeanor) of a small terrier. The car is nearly 30 inches long and tops 35 mph at its fastest. While four-wheel drive ensures the grippiest traction on any surface, the X-Maxx also has self-righting technology. That means if you overturn it on a tight corner, you can hit a button on the remote and it flips back on its wheels and keeps right on going.

HIT LIST

10 Great Ideas in Gear

1 BEVEL TRIMMER

Not much has changed in the electric-clipper space—your barber likely uses the same tools as the one before him. Bevel's Trimmer looks and works like it's from the future: a cool blue LED, reduced vibration, and a dial to adjust blade alignment. Timeless tool, meet modern age. **\$180**

**10 ELLUM**

Ellum's motion-sensing lights illuminate as you move past them and dim as you leave. The wood-grain lamp can be mounted to walls without having to drill a hole, which we'd say is a recipe for enlightenment. From **\$129**

**2 AXEL AUDIO**

We all have our favorite genres of music. Axel Audio's line of headphones is tailored to your preferred style: Deep for the bass lover, Pure for the instrumentalist, and Core for the balanced pop enthusiasts. From **\$145**

3 NONDIA ZUS CHARGER

Lots of smartphone chargers attach to a car's cigarette lighter. But few offer a second USB charging port for passengers. Fewer still can help you find your car on a map via smartphone—this does both. Never go hunting for your car again. **\$34**

4 SANDISK IXPAND

Moving photos and videos off your phone to free up storage space is annoying. SanDisk makes it easy with the iXpand flash drive. Plug it into your iPhone and instantly store up to 128GB of data. Never delete one video to record another again. From **\$60**

by
XAVIER HARDING

5 MOTO 360 SPORT

Smartwatches don't have to be precious. Motorola's 360 Sport is rugged enough to survive your workout—that's because it's also a fitness tracker. The silicone band, heart-rate sensor, and round display are fixed inside an enclosure that's dust- and water-resistant. **\$299**

6 BEELINE

Clear directions are crucial for bikers mid-ride. But who wants to hold a cellphone and look at the map app while peddling? Beeline is a compass-size handlebar attachment that knows where you're going, and uses an e-ink screen to get you there. **\$69**

7 LUCI

Solar-powered? Waterproof? Collapsible? Check, check, and check. Luci's portable light also has a loop hook for easy hanging anywhere. An extra \$10 gets you color-changing abilities. Thomas Edison would be proud. **\$15**

8 JETBLADE

Hydro boosters for your feet. There's nothing more to say—except that it works only on water. **\$6,000**

9 GRAMOXOV

For those who've wondered, "Why doesn't anyone make a vertical turntable?" Gramoxov does, and it's the coolest vinyl player around. Once again, analog stands tall. **\$400**

Haiku Lights

Featuring onboard occupancy and light sensors, this LED fixture conserves energy by turning off when you leave and dimming when it detects daylight.



Haiku Fans

As room temperature changes, Haiku Fans adjust automatically to improve comfort while reducing HVAC energy use – night or day, winter or summer.



Haiku Wall Control

Packed with sensors and a learning microprocessor, the Haiku Wall Control communicates with your fans, lights and HVAC system to create a more comfortable, efficient home.



Building a Better Home

Haiku® Home – a suite of home products designed and manufactured by Big Ass Solutions® – brings award-winning design and meaningful technology together. Haiku fans and lights keep your home comfortable, respond to your presence and conserve energy – automatically.

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Mercedes' newest concept is autonomous with holographic displays

The impending arrival of autonomous vehicles has a lot of engineers wondering: What will the interior of a smart car look like without the steering wheel, pedals, and gauges? And what will we do with ourselves if we're not driving?



by
ERIC ADAMS

Mercedes-Benz has a feeling we'll hang out like we're on a futuristic party bus.

The company's Vision Tokyo concept car, unveiled at the Tokyo Motor Show, is aimed at drivers who love their digital toys. A circular leather couch that seats up to five people dominates the interior space. It wraps around what designers say will be a holographic display, capable—in theory—of projecting maps, games, music choices, and other apps that passengers can use as they ride along in electric-car silence.

The car's single door takes up the entire left side and swings open like one of the falcon doors on a Tesla Model X. To enhance that vibe even further, the design team added color-changing LEDs along the car's grill and massive

26-inch wheels, giving it a look right out of *Tron*.

But the car's best features aren't even visible: The engineers at Mercedes built the Vision Tokyo to learn as it drives autonomously. That means that with each journey, the car will learn more about its occupants and their preferences. Add that the car has a hybrid battery and a fuel cell engine, puts out zero emissions, and has a 600-mile range on a single charge. It's obvious why you'd want one.

In case passengers are not ready to embrace the future with empty arms, a steering wheel folds down, letting them take control—assuming anyone inside still has a driver's license.

The Mercedes-Benz Vision Tokyo's electric hybrid system can drive 118 miles on batteries and more than 490 miles on electricity produced by its fuel cells.

Ask an Expert

YOUR PODCAST EMPIRE AWAITS

It took him 20 years, but Leo Laporte has built a podcasting empire that rivals the old-school broadcasters. He has more than 20 shows (*This Week in Tech* being a must-listen), which reach a combined 5 million people each month. His California home doubles as his TWiT's Brick House studio, and is littered with high-end tech to record, mix, and upload talk-show-quality content. Even if you're a few podcasts short of an empire, this gear will set you on the right track.



TIPS FROM LEO

BUILD A COMMUNITY

The approachability of podcasting makes it difficult to rise above the noise. This is a question much larger than podcasting; it's happening across all media. If you can build a community around what you do—whether as a podcaster or even video-maker—that community will buoy you and support you and grow your audience.

DON'T CHASE AN AUDIENCE

No one doing a podcast should say in calculated fashion, "Let's do something that's going to make a lot of money." It might work short-term, but real successes come from people authentically speaking their truth. In new media, one has to find a voice—but we're only just beginning. We haven't found the Ernie Kovacs of podcasting.

TALK ABOUT WHAT YOU LOVE

I choose panelists based on whom I'd love to hang around and chat with. Because on a slow day, when there's no Apple news, we'll just talk about *Star Wars* or whatever. It's much less agenda-driven than a television broadcast. A lot of podcasting is hanging out with your buddies, talking about something you're interested in.

Trending

MARCH/APRIL 2016

360

That's how
many degrees
you can
expect to
shoot in from
now on.



VIDEO THAT TURNS HEADS

Stop being so one-directional. Today, a raft of new 360-degree cams provide the most immersive video you can get—short of putting on a virtual-reality device. Compact and light, they can capture people, places, and action anywhere. Here are the best options for shooting around.

①

BUBL'S BUBLCAM

The Bublcam's Xplor mobile app allows for previewing, stitching (to enable playback), and sharing, right on your smartphone. That's a much-needed portable solution for road warriors everywhere. Android and iPhone users can view their videos in VR with the help of Google Cardboard.

\$799

②

LUNA

Billed as the world's smallest 360-degree camera, this black ball looks like the eye of a robot. A waterproof body and scratch-proof lens means it can survive any situation you throw it in. Wireless data transfer and inductive charging means less time plugging in cables.

\$375

③

KODAK PIXPRO SP360

The Pixpro makes Kodak moments a lot more momentous. The camera's app lets you use your iPhone or Android device as a viewfinder or to pause recording. And you don't have to worry about already-shot video clogging your memory. Support for expandable storage via microSD cards ensures you have the space you need for the shot you want.

\$300

by
XAVIER HARDING

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Now

The Platform

MARCH/APRIL 2016



EVERYONE WILL BE A GAMER IN THE FUTURE



If you haven't heard of Razer, you're not spending enough quality time with your video games. The 10-year-old, \$1 billion company practically invented the gaming-peripherals market. It doesn't sell the games; it sells millions of high-tech computer mouses, headphones, and keyboards to the gamerati. Sort of like the folks who sold pickaxes during the gold rush. Now, Razer CEO Min-Liang Tan—a self-proclaimed game geek and a former video-game pirate—is looking to expand his empire with the release of a laptop, a streaming device, and a virtual-reality headset. Tan recently spoke to *Popular Science* about his obsession with gaming and the future of playing.

How did this all start?

I used to play video games competitively back when e-sports was still called "Pro Gaming." I was living in Korea, and my friends and I were always looking for a competitive advantage during sessions of *Quake*

Were you always into shooters?

Yeah, but I also liked role-playing games. *Wasteland* is another game that had a big impact on me. I remember pirating it a long time ago. Then one day I met the game director, Brian Fargo. I said, "Dude, I'm really

by
MICHAEL NUÑEZ

To stay focused on the gamers. When we talk to other people about using our technology—whether they're focused on military or healthcare or space technology—we always say, "We're happy for you to modify and use our products, but we really just want to make products for gamers."

Where is gaming headed?

It's definitely going to be a lot more immersive. And when I say immersive, I don't mean in the sense of what's happening in virtual reality; I mean in the form of what's happening with multiplatform games.

What do you mean?

Content is going to be served up in so many different places: mobile to PC, PC to console, PC to wearables. There could be a game that sends you text messages, or there could be Xbox characters who share social-media interactions with you. The lines are going to be incredibly blurred when it comes to how people interact with games.

So are we still at the tip of the iceberg?

Absolutely. The future is incredibly bright for gaming. Our biggest bet as a company is that gaming is going to be the biggest form of entertainment—bigger than movies, bigger than music. We believe there are anywhere from 2 billion to 3 billion gamers out there. And it's more accepted than ever. Gaming appeals to a basic tenant of human nature: It's all about having fun.

The future is incredibly bright for gaming. We believe there are 2 billion or 3 billion gamers out there.

3, Unreal Tournament, and other first-person shooter games. We were willing to try anything. We were always talking about how to hack our computer rigs to make everything a little faster. Keep in mind, all the mouses and keyboards back then were slow. So we got together with some IT guys and engineers and, in 1999, designed a better, more responsive mouse.

sorry for pirating it." He loved my story so much, he made me a character in *Wasteland 2*. It still blows my mind. I was a total fanboy over his work, and it was such a cool moment to find out he's really excited about the work we do.

What's the greatest challenge to growing a gaming-hardware company?

BIKE TIRES THAT CAN SURVIVE THE HIMALAYAS

With plenty of tread to spare

VITTORIA MORSO G+
AND VITTORIA MEZCAL G+
PRICE: \$70 per tire

When you're mountain biking in extreme conditions, you want tires that are light enough for nimble handling, sticky enough to grip rocky and rooty trails, and tough enough to last. Most can't do it all: Beefy tires have bite, but they're sluggish; light tires are nimble, but they wear out quickly or puncture.

Vittoria's new Mezcal and Morsa tires eliminate that trade-off once and for all.

by
BERNE BROUDY

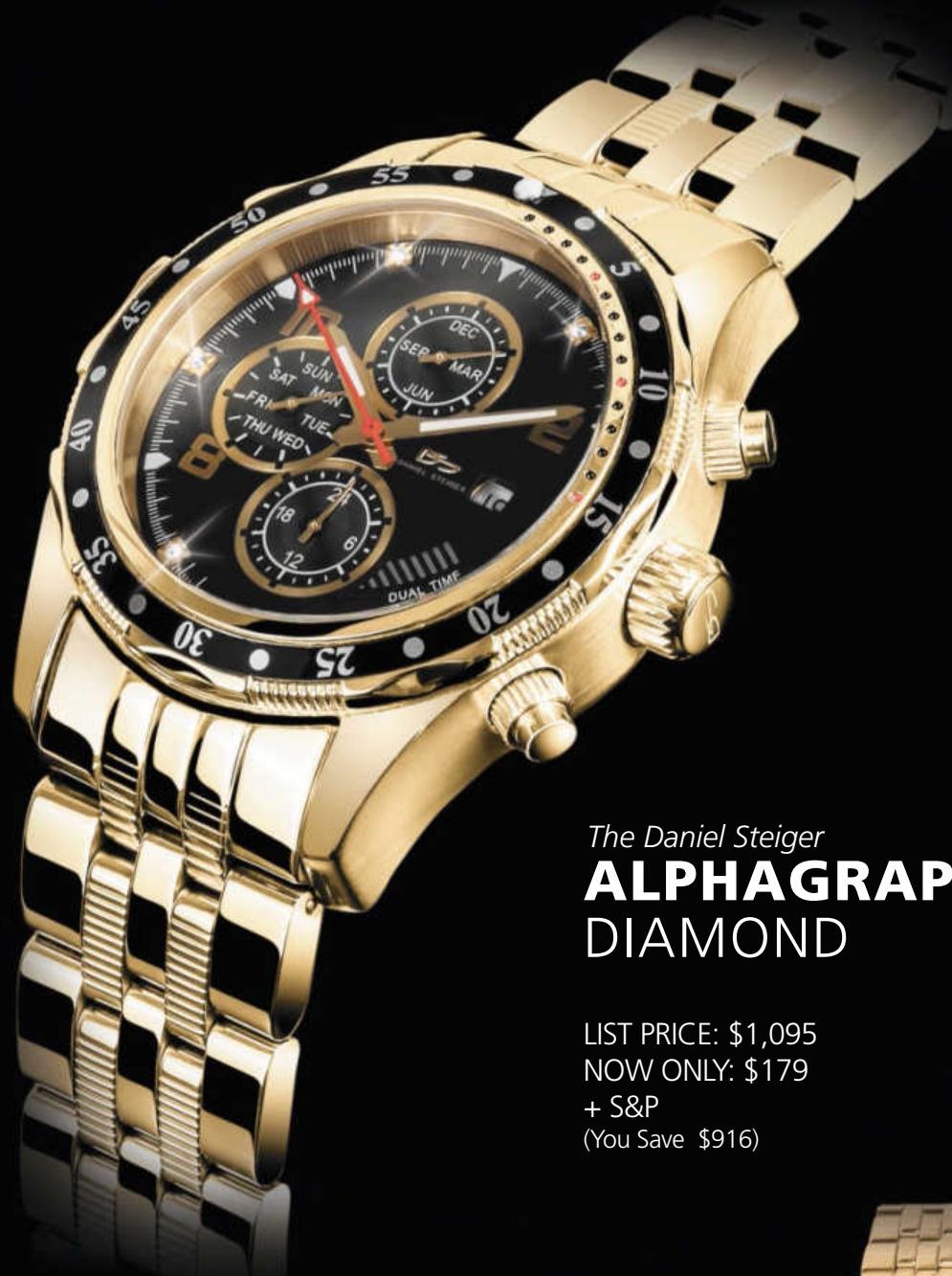
Vittoria uses graphene that is two to eight atoms thick—nearly invisible.

They are infinitely tough and elegantly maneuverable.

Here's why. Graphene, in its most basic form, is a sheet of pure carbon just a single atom thick. It is half the density of aluminum, which means it's light and extremely elastic.

Vittoria uses graphene that is two to eight atoms thick—nearly invisible. By adding it to mountain-bike tires, Vittoria achieves the dream combo of characteristics—light, sticky, and tough—that rubber can't on its own. In fact, adding graphene to rubber creates a tire that changes depending on how you ride. When riding on a straightaway, the tire stays relatively hard. When braking or cornering, it softens. Examining how graphene responds to accelerating and turning corners, Vittoria constructed them in a way that allows the top and bottom layers to react differently during use.

Vittoria can't say exactly how many miles to expect from these tires—that depends on trial conditions and how hard you ride. Leading up to and on a recent trip through Nepal, I put hundreds of miles on the Morsa and the Mezcal. Fellow bikers' tires lost pressure on a daily basis; they'd spin out on a slippery rock. On descents, the tires gripped on rock and dirt alike—letting me ride faster downhill than I ever have. Quite a few of my fellow riders ended up throwing their tires in the post-trip trash heap. After my 13-day trip, my Morsa and Mezcal were dusty but barely worn, and should still last me for several months more of regular rides.



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Case & Bracelet Material: Solid Stainless Steel 18k Yellow Gold

Sub-dials: Month, Date, Dual Time & Day **Case Features:** Screw Down Crown & Buttons Rotating Bezel

Bracelet: Stainless Steel Adjustable With Divers Buckle **Water Resistance:** 10ATMs





The explosion occurred just 15 seconds after launch, and the hazard area stretched for 1,400 square miles.

Want more about Orbital ATK's next launch? Check out popsci.com/antares.

Next

EDITED BY BREANNA DRAXLER + MATT GILES

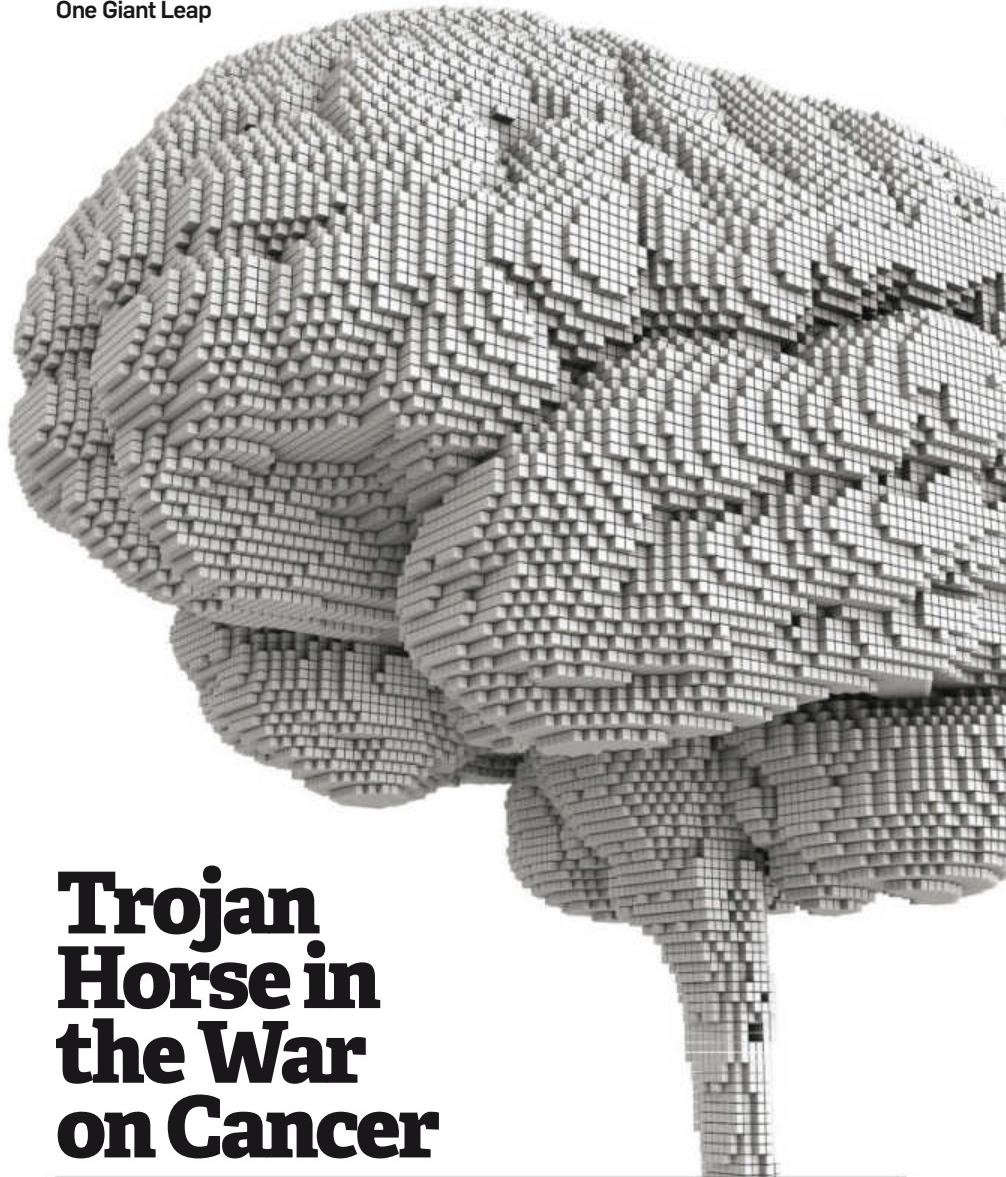
A dramatic photograph of a massive fire at a rocket launchpad. The sky is filled with intense orange and yellow flames and smoke, casting a fiery glow over the scene. In the foreground, a tall street lamp stands on the left, and a chain-link fence runs across the bottom. The fire appears to be engulfing the base of a rocket or its support structures.

No one ever said rocket science was easy. In October 2014, a routine delivery to the International Space Station of a few thousand pounds of science equipment and foods blew up just after launch. There weren't any injuries, but the accident has kept the *Antares* rocket—and its makers, Orbital ATK—grounded for a year and a half. A faulty turbopump in one of the main AJ-26 engines was to blame, so the company gave *Antares* a whole new engine, the RD-181. When the *Antares* 230 rises from the ashes in May 2016, it'll be more powerful than ever, capable of carrying an extra 1,300 pounds of cargo.

by
SARAH FECHT

15

Cost, in millions of dollars, of repairing the *Antares* launchpad in Virginia, which NASA and Orbital ATK share



Trojan Horse in the War on Cancer

Your body has an excellent defense system for keeping toxins out of the brain: the blood-brain barrier. But this border patrol also keeps drugs out, which presents a real problem for treating tumors and other maladies.

In November, a team from Sunnybrook Health Sciences Centre in Toronto hacked the system by creating temporary new entrances. Doctors injected microscopic air bubbles into a cancer patient's bloodstream, and then focused sound waves onto blood vessels near the growth. This caused the bubbles to vibrate violently, poking holes in the barrier just big enough for a

chemotherapy drug to pass through.

These holes closed back up hours later.

This method could also enable targeted drug treatments for diseases such as Alzheimer's or Parkinson's. "It opens up a whole world of possibilities," says neurosurgeon Todd Mainprize, the team's lead researcher. "We could treat things we couldn't treat before."

by
LYDIA CHAIN

WASTE NOT, WANT NOT

When bacteria feed on excrement and other waste, what's left is sludge. And that sludge is "a secret goldmine," says Paul Westerhoff, an environmental engineer at Arizona State University. He means it literally: Westerhoff estimates that large quantities of gold, silver, and other valuable metals seep into biosolids from a variety of sources, including industrial processes and teeth fillings. Until miners target these metals, society will keep flushing millions of dollars down the toilet. **NICOLE LOU**

BY THE NUMBERS

57 POUNDS

Amount of sludge a person produces annually

\$550

Value of metals in a ton of sludge

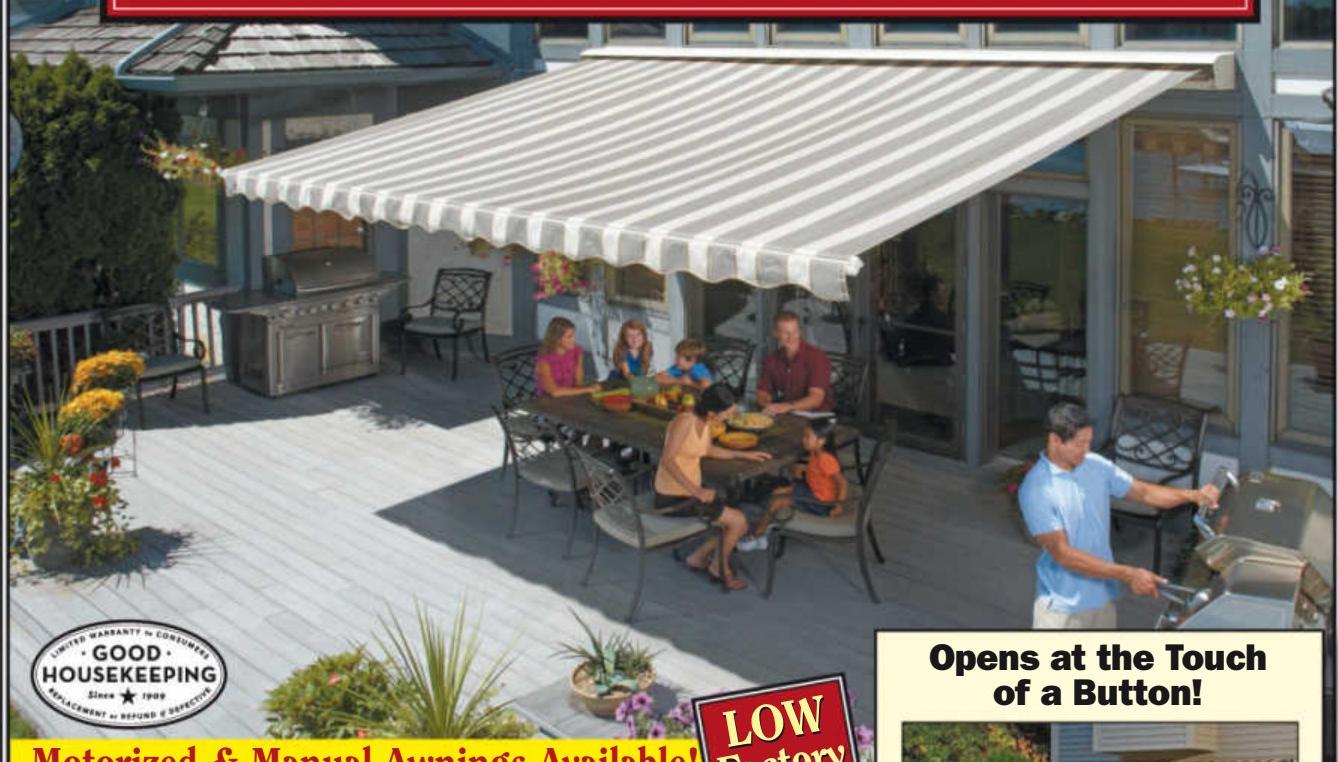
\$8 MILLION

Estimated worth of gold and silver that could be mined annually from the waste of 1 million people

\$13 MILLION

Estimated worth of all metals that could be mined annually from the waste of 1 million people

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Marcia McNutt

On the Power of Discovery

The incoming president of the National Academy of Sciences, Marcia McNutt, arrives at the U.S. advisory agency at a crucial moment. Technology is rapidly changing the nature of research, and science education needs to keep pace. Luckily the marine geophysicist, whose term begins in July, has spent her career collecting data, tracking environments, and creating models of our changing world. She's pro-curiosity and bullish about the impact that big data could have on scientific discovery.

As told to
MATT GILES



7.0

Amount, in billions of dollars, spent outfitting K-12 classrooms in the U.S. with computers and tablets in 2014, according to IDC

“

Scientists have always been explorers—they've had to go out and brave the world to make new discoveries. Darwin found unusual finches, and that led to the theory of evolution. But with advances in computing power, scientists won't necessarily have to leave their homes anymore. Future exploration will start with algorithms.

Explorers can come up with crazy theories, use computers to sift through our wealth of data, and pull the signal out of the noise, answering the questions: 'What am I looking for here? What is important?'

By 2023, a single computer's processing power will equal that of the entire human race. If you apply that processing power to all the information out there, imagine the

discoveries we will make. Adventurers won't have to get a queen to give them a ship to explore anymore. Every schoolchild could be a digital Lewis and Clark.

I can't help but believe we're on the threshold of mind-blowing discoveries about

the worlds beyond our solar system. People thought Pluto would be dull, and its flyby was amazing. We are going to look at planets like Neptune and Jupiter and say, 'We thought they were interesting, but the real variety is out beyond Pluto.'

There is a very real possibility that we'll soon learn more about the special conditions that gave rise to life on Earth.

“Children love discovery. We should teach them the fundamentals and then set them loose.”



"For a while, we thought our planet was unique because it was so active, and all of that activity created energy sources that life needs. But now we see that happening in lots of places in our solar system. Maybe we aren't so different after all. We need to keep exploring to find out."

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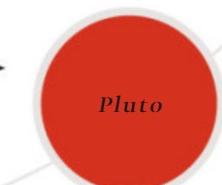
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OUR SOLAR SYSTEM HAS A NINTH PLANET

And it's still not Pluto

The real deal is 5,000 times more massive than the former titleholder, and a whole lot farther away.



The sun's scorching heat meant only the small, dense planets of our solar system survived.

A 20,000-year orbit

Like the outer gas giants, this new one will likely have a rocky core covered in methane and nitrogen ices.

Dwarf planets are a dime a dozen. When it comes to real planets—bodies with enough mass to achieve a nearly round shape, clear nearby debris, and orbit the sun—we know of only eight in our solar system. Over the past century, many astronomers claimed to have caught whiff of an elusive ninth body: Planet X. The latest to make this assertion is the same man who demoted Pluto.

"We've found evidence of a giant planet in the outer solar system," says Mike Brown, an astronomer at the California Institute of Technology. "By 'giant,' I mean the size of Neptune, and by 'outer solar system,' I mean 10 to 20 times farther away than Pluto."

What led Brown to this grand announcement was the discovery of an unusual alignment of dwarf planets with eccentric orbits. "You can think of them like hands on a clock, all moving at different rates," Brown says. The chance of this arrangement being coincidental is just 1-in-100, so Brown called on Caltech theoretical astrophysicist Konstantin Batygin to figure out the forces at play. After a year of supercomputer simulations, Batygin says the only explanation is the gravity of a planet 10 times the mass of Earth.

The team published their mathematical evidence in January. Alessandro Morbidelli, a planetary scientist at France's Côte d'Azur observatory, calls it "the first solid and convincing demonstration that there is a planet that could create this anomaly." Now they just need to find Planet X (or Planet 9, as they call it) in the sky. Brown has already secured telescope time, but he doesn't want the search to be a solo endeavor. "The paper is a roadmap for anyone to look," Brown says. "I need to know the answer more than I need to be the discoverer."

by
SHANNON STRONE

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Introducing The new and revolutionary Jacuzzi® Hydrotherapy Shower.



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As we age, the occasional aches and pains of everyday life become less and less occasional. Most of us are bothered by sore muscles, creaky joints and general fatigue as we go through the day- and it's made worse by everything from exertion and stress to arthritis and a number of other ailments. Sure, there are pills and creams that claim to provide comfort, but there is only one 100% natural way to feel better... hydrotherapy. Now, the world leader in hydrotherapy has invented the only shower that features Jacuzzi® Jets. It's called the Jacuzzi® Hydrotherapy Shower, and it can truly change your life.

For over 50 years, the Jacuzzi® Design Engineers have worked to bring the powerful benefits of soothing hydrotherapy into millions of homes. Now, they've created a system that can fit in the space of your existing bathtub or shower and give you a lifetime of enjoyment, comfort and pain-relief. They've thought of everything. From the high-gloss acrylic surface, slip-resistant flooring, a hand-held shower wand, a comfortable and adjustable seat, to strategically-placed grab bars and lots of storage, this shower has it all.

Why wait to experience the Jacuzzi® Hydrotherapy Shower? Call now... it's the first step in getting relief from those aches and pains.

AGING = PAIN

For many, arthritis and spinal disc degeneration are the most common source of pain, along with hips, knees, shoulders and the neck. In designing the Jacuzzi Hydrotherapy Shower, we worked with expert physicians to maximize its pain relieving therapy by utilizing the correct level of water pressure to provide gentle yet effective hydrotherapy.

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Concepts & Prototypes

Glider with a Stellar View



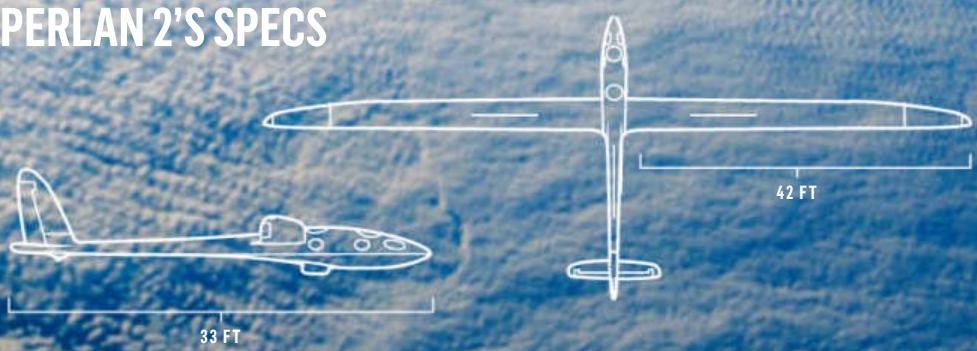
This summer, two pilots sandwiched in a 36-inch-wide cabin could take the Perlan 2 glider to 90,000 feet, higher than most aircraft have flown. To reach such heights, the glider will ride stratospheric waves—powerful and little-understood currents that flow over mountain ranges. It will be flying in uncharted and unstable aeronautic territory, and between the rigors of thin air and blistering ultraviolet radiation, the slightest miscalculation could be disastrous. If successful, the Perlan 2 could expand the parameters of high-altitude flight, enhance climate science, and provide new insights on planetary exploration. All without burning a drop of jet fuel.

by
**SHELBY
CARPENTER**

1. ASSISTED LAUNCH

A 20 horsepower tow plane will use a cable to lift the glider up to 10,000 feet. Perlan 2's pilots will then detach from the aircraft and continue their ascent using air currents and lithium-ion battery-powered flight instruments.

PERLAN 2'S SPECS



2. TIGHT QUARTERS

Engineers built the 3-by-10-foot pressurized fuselage as small as possible to minimize drag and weight during flight. The cabin is circular (rather than the oval shape of most aircraft), so air pressure will push equally on all sides.

3. TREATED WINDOWS

At 90,000 feet, the glider will be exposed to the deteriorating effects of solar radiation. A coating on the polycarbonate windows will absorb the rays. It will also help protect against frigid temperatures and maintain the Perlan 2's structural integrity. If the windows crack, the cabin will depressurize and the pilots' lungs will explode inside their chests.

4. UNIQUE WINGS

Lightweight carbon-fiber wings help the glider to fly in the low-density air of the upper stratosphere. The airfoil—its aerodynamically shaped, 84-foot wingspan—maximizes efficiency and provides the ideal ratio of lift to drag.

5. STEADY FLYING

Along with a control stick, pilots will use ailerons and elevators—the movable sections of each wing—and a rudder to navigate turbulence. These help control the glider's pitch, roll, and yaw.

6. SAFE DESCENT

Without an engine to modulate its speed, the Perlan 2 will rely on airbrakes, which flip open and create drag to safely land. In case of a midflight emergency, the pilots can also deploy an 11-foot-diameter drogue parachute, often used by high-speed aircrafts.

7. SCIENCE MISSION

The glider will be the first to collect scientific data on the powerful—and unpredictable—stratospheric waves. Aviation experts will use this research to forecast the waves more accurately, eventually enabling passenger planes to operate in the upper atmosphere, where they could fly farther and faster on less fuel (thanks to the reduced drag).

"This area has the most intense turbulence outside what you'd get in a hurricane or a cyclone. It's like you're in a washing machine."

—Morgan Sandercock, project manager

8. MARTIAN ANALOG

The glider's flying conditions will be similar to those found on Mars, and the team hopes to share any insights the craft gleans from its flight. "Somebody will build an airplane for Mars someday, and we'll have a wealth of data for that person," says Ed Warnock, the project's CEO.

9. CLIMATE DATA

The flight has additional scientific implications. When the waves stretch high enough, they break, and chemicals from the troposphere are thrust into the stratosphere, where they can remain for decades. No one knows the effects of this atmospheric cocktail, and whatever data the Perlan 2 collects could help sharpen the forecast of humanity's effects on climate change.

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Are We Ready for Designer Babies?

by
CLAIRE MALDARELLI

When Chinese researchers reported using a technique called CRISPR/Cas9 to edit the genome of human embryos this past April, they sparked a worldwide debate over how this technology could (or should) be used. Scientists expressed legitimate fears: What are the side effects? Will this open the floodgates to designer humans? The world's foremost geneticists, biotechnologists, and bioethicists gathered in Washington, D.C., in December to address those questions and map the future of human-gene editing.

CRISPR isn't the first genome-editing tool, but it is by far the best.

86

Number of human embryos a Chinese team edited last year to alter the gene HBB, which can cause a fatal blood disorder

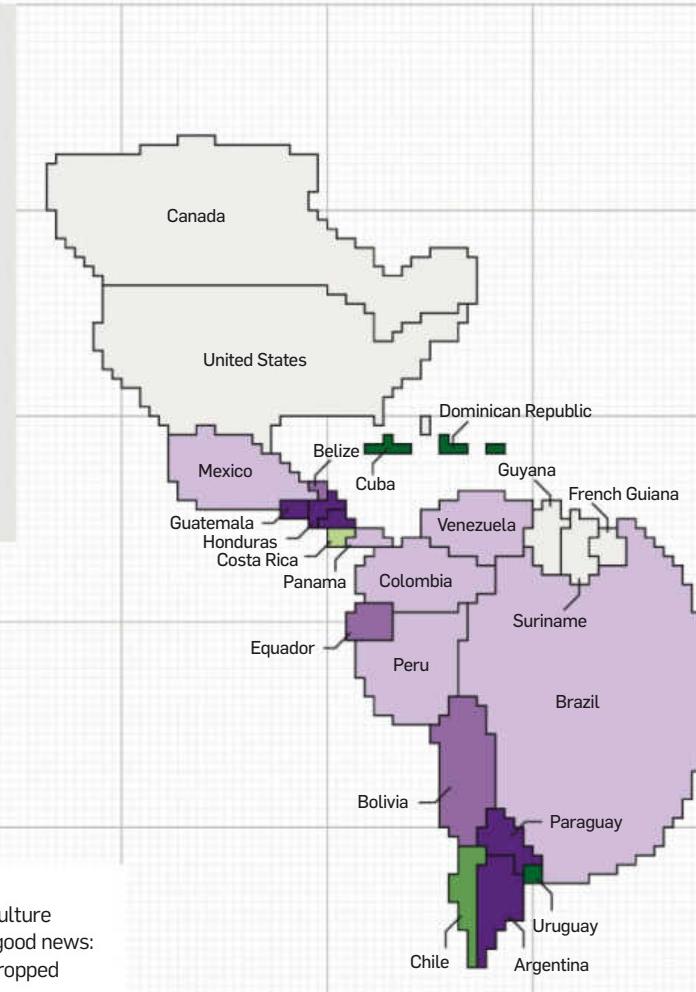
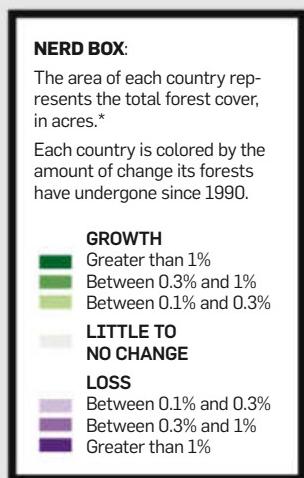


“CRISPR’s potential to treat human diseases is very high, but so is its potential damage.”

—Gang Bao, bioengineer at Rice University

In order to better assess the risks, scientists at the December summit agreed that basic research should progress. But they essentially called for a moratorium on editing human embryos for pregnancies. George Daley, director of the stem cell transplantation program at Boston Children's Hospital, says CRISPR is still too unpredictable for a baby to be brought to term. "But the science is essential for informing the debate," he says.

Such conversations can't just occur within the walls of a conference center. As CRISPR's power comes into focus, public discussion should proceed in tandem. Without societal buy-in, Daley says, gene-editing research could be misunderstood—and that would undermine its many potentially life-changing benefits. 



The Future of Trees is Looking Up

by
BREANNA DRAXLER

According to the FAO, the forest industry, like logging and paper products, adds \$600 billion annually to the global GDP.

In September, the Food and Agriculture Organization released a rare bit of good news: The global rate of forest loss has dropped 50 percent in five years.

In northern regions, commercial planting has even expanded forests. "The only way to supply things like amazon.com packages and toilet paper is tree plantations," says Kenneth MacDicken, a former FAO senior forestry officer, who led the report. Not all countries are sighing with relief, though. In the southern tropics, where forest clearing can be a matter of human survival, the practice continues.

Climate change exacerbates the stress on forests, says Mary Wagner, associate chief of the U.S. Forest Service, leading to drought, wildfires, invasive species, and disease outbreaks.

Fortunately advances in data collection and remote-sensing put foresters in a good position to find solutions. "We've never been better prepared for managing forests," MacDicken says.

ECUADOR

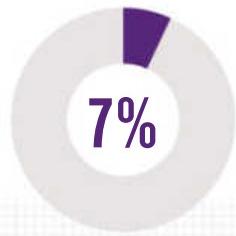
↓ 210,000 acres/year

Yes, its forested area continues to drop, but Ecuador cut its rate of natural forest loss in half by paying landowners to maintain a forest's beneficial functions, such as carbon sequestration and water filtration. "Water doesn't come from a faucet," Wagner says. "It comes from a forest."

BRAZIL

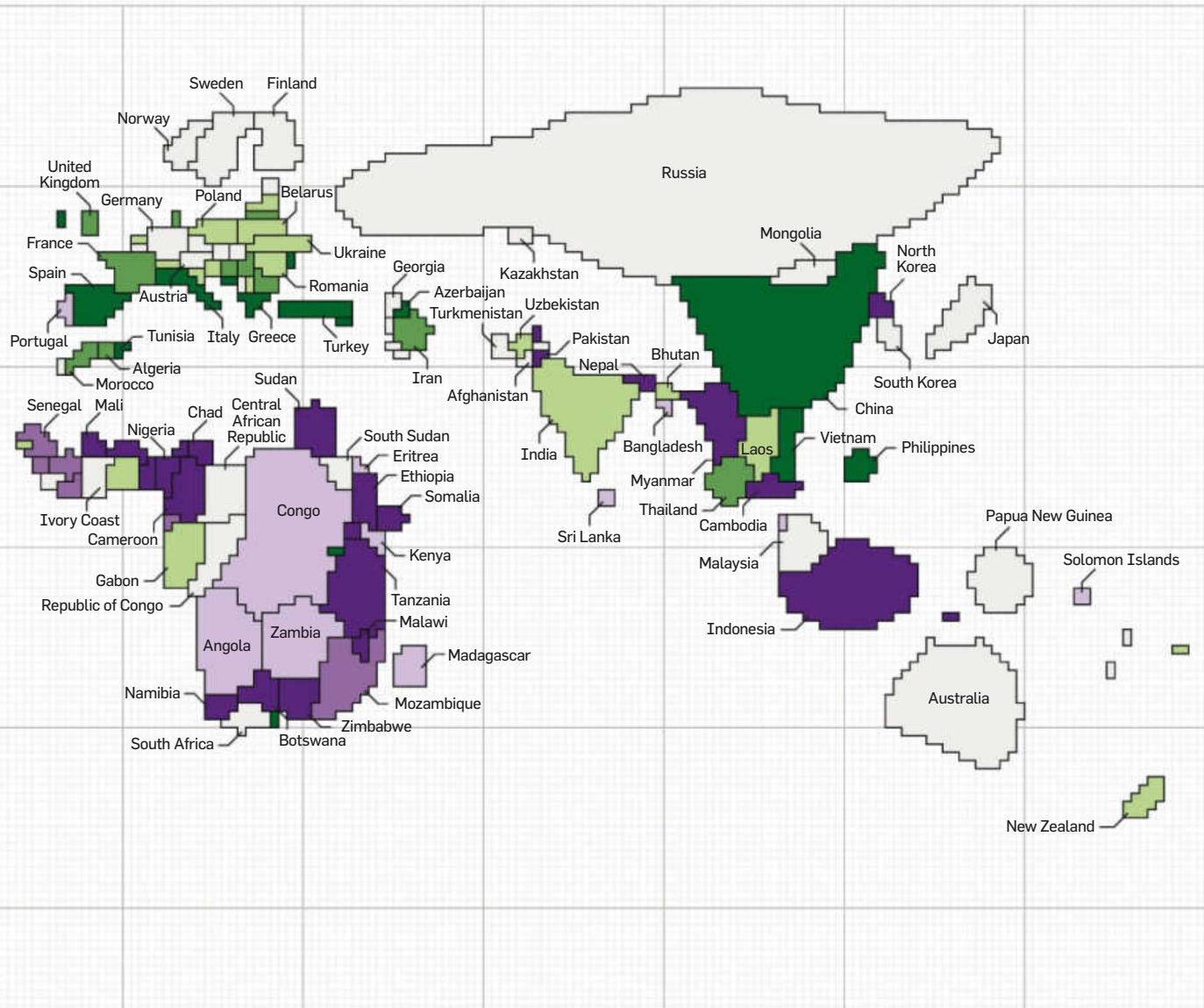
↓ 5.7 million acres/year

With massive tracts in private hands, Brazil's forest is particularly vulnerable. But a law now requires that landowners retain 80 percent of their property as forest. "That means they can't convert everything to rangeland or farmland," MacDicken says.



In 2015, the amount, by area, of the global forest cover that was planted rather than natural

MARCH/APRIL 2016



SOURCE: © FAO 2015 "GLOBAL FOREST RESOURCES ASSESSMENT," ACCESSED SEPTEMBER 29, 2015

UNITED STATES

↑ 760,000 acres/year
Because of increasing urbanization, 83 percent of the U.S. population now lives in a city. While the U.S. boasts nearly 477 million acres of public forests, Wagner points out that its 321 million acres of urban forests are perhaps more impressive.

EUROPE

↑ 2.1 million acres/year
Despite sweeping historical deforestation, much of the European continent is on the upswing thanks to secondary-forest growth. "Europe has relatively little natural forest left, but you'd never know that," MacDicken says. "The planted forests are well-managed, well-maintained, and getting on in years."

SOUTH AFRICA

Holding steady
Pulp and paper companies in South Africa have established a profitable tree-plantation industry. But, as is the case with many developing countries, access to water limits expansion.

INDIA

↑ 670,000 acres/year
A rapidly expanding rural population in India means more people are relying on wood for fuel. And that has led to more small farmers planting trees for additional income. "Fast-growing, short-rotation tree plantations reduce the pressure on natural forests," MacDicken explains.

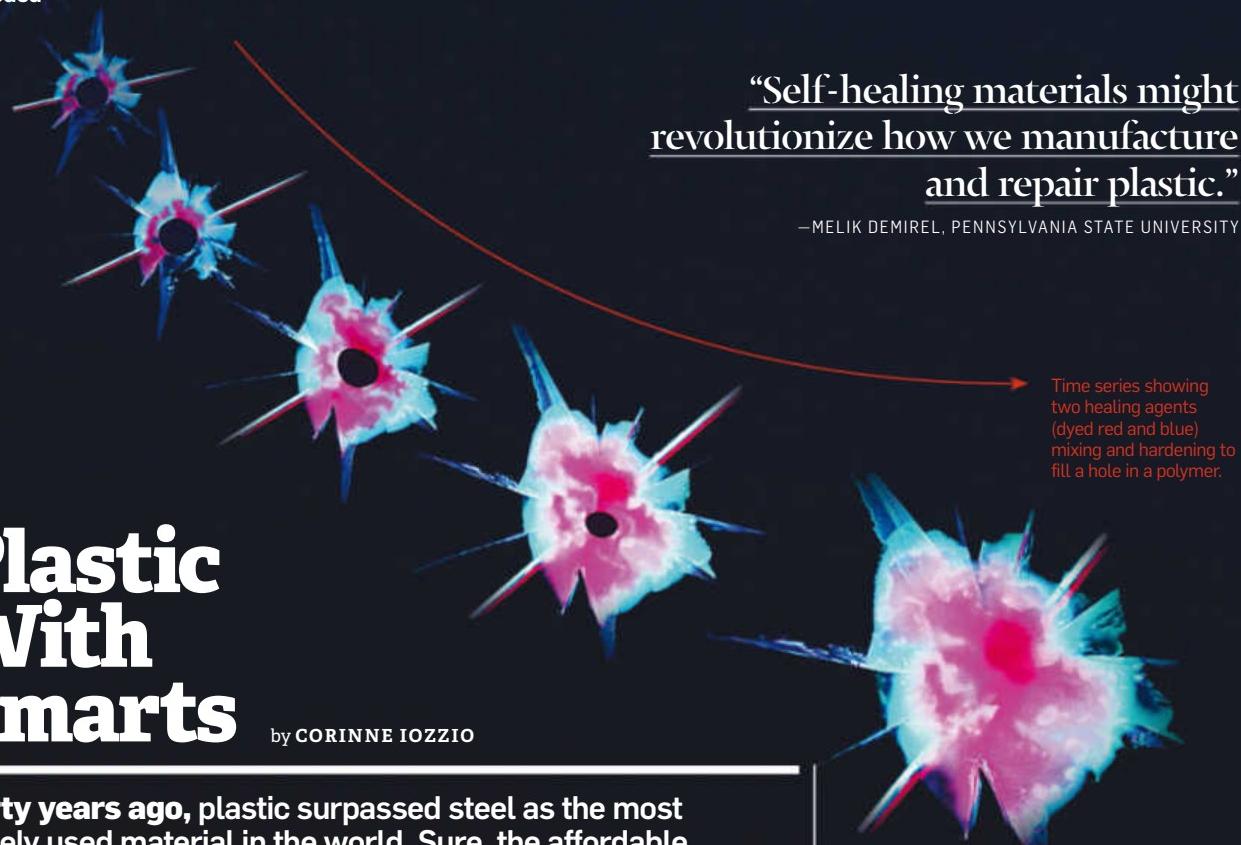
CHINA

↑ 5.1 million acres/year
China's immense investment in planting forests—enacted to stop the expansion of the Gobi Desert as well as the increase of carbon dioxide in the atmosphere—is paying off. Coupled with natural progress, China's forested acreage has grown tremendously in recent years.

INDONESIA

↓ 2.7 million acres/year
A highly decentralized government dispersed across the country's thousands of islands makes monitoring forests difficult. A whole-log export ban brings some economic relief via job creation: When trees are cut down, the lumber must at least be processed locally before export.

Decoded



Plastic With Smarts

by CORINNE IOZZIO

Forty years ago, plastic surpassed steel as the most widely used material in the world. Sure, the affordable and malleable polymers have brought plenty of convenience to modern life (Tupperware! Teflon! Velcro!) as well as taking on more-vital roles, in airplanes, cars, and smartphones. There's a catch, however:

Unlike many of the metals it replaces, plastic is really hard to fix; even invisible fractures can compromise its strength. A new class of smart plastics can heal breaches all on their own, to mend cracked phone screens or stitch up airplane wings.

Nancy Sottos helped pioneer this field in the '90s. Her team at the University of Illinois at Urbana-Champaign has developed composites that can repair themselves using a range of methods. One extends the life span of ships, bridges, and windmills by repairing plastic coatings on

metal structures. "Scratches compromise traditional coatings," Sottos says, which can lead to rust. An early self-healing plastic, now sold by spinoff company Autonomic Materials, has microcapsules embedded throughout it. When the plastic cracks, the capsules burst, releasing resin and a catalyst, which react to fill the crack.

For things made entirely of composites, like car bumpers or airplane wings, microcapsules won't cut it. Once the capsules are spent, no more healing can occur there. One of Sottos' newest composites is laced with channels that can deliver the self-healing agent to fill cracks again and again. The material was able to heal the same spot 30 times in the lab. But Sottos says it could be 20 years before it's reliable enough for safety-critical applications (i.e., we'll have self-healing bumpers long before self-healing airplanes).

Materials in extreme environments require even more ingenuity. Instead of relying on an onboard catalyst, engineer Melik Demirel of Pennsylvania State University created a polymer whose healing reaction is triggered by water, along with

heat and pressure. Its proteins mimic those of squid teeth, which heal themselves by reconnecting broken hydrogen bonds. "Hydrogen bonding is how nature puts everything together," Demirel says, so the mended material is restored to its original chemical makeup and therefore regains its original strength. So far, his team has fixed dog chew toys and mock Legos. In the future, the method could repair deep-sea fiber-optic cables.

Eventually, self-healing plastics could go to space. Scott Zavada, a polymer scientist at the University of Michigan, devised one that sandwiches an air-reactive liquid between layers of polymer. When the polymer gets punctured, air inside the vessel reacts with the liquid, hardening it in less than a second. It could someday seal holes punched in Mars habitats by flying debris.

Going forward, Sottos has her eye on what she calls "forever material." Our bodies and other natural systems regenerate themselves again and again yet never really change shape. So she wonders if polymers could one-up nature: "What if you had a material that didn't age?"

0.4

Diameter, in inches, of a hole that current versions of self-healing plastic can successfully repair

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- Digital sound processing chip provides crystal clear sound and makes speech easier to understand without feedback
- Multiple memory programs adapt to most listening situations
- Nearly invisible thin tube design
- Long lasting size 13 batteries and a low battery warning
- 10 bands of layered noise reduction helps to emphasize voices while balancing out background noise
- 100% Money Back Guarantee

5 Star Reviews! ★★★★★

Wonderful Company! "I will definitely recommend your company to my patients." - **Dr. Arun P.**

They Are Fantastic! "I just received my HCX hearing aids and they are fantastic. Advanced Affordable is far superior and far more affordable!" - **Chuck D.**

Studies Show That Hearing Aids May Help Prevent Dementia.

A study by Dr. Frank Lin at John Hopkins University, found that adults with hearing loss are significantly more likely to develop dementia and at a faster rate. Fortunately, using hearing aids is an effective way to treat hearing loss and may help you maintain healthy mental activity.

Read More Information At:
www.AdvancedHearing.com/Dementia



- A) Microphone
B) Volume Control Wheel
C) Program Button
D) Long Lasting Battery
E) Digital Signal Processor
F) Receiver (Speaker)
G) Sound Tube

More Technical Information At:
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Digital Hearing Aid Technology... For Only \$299!

All hearing aids work the same way. The **microphone** picks up the sound and sends an electrical signal to the **digital signal processor**. The **digital signal processor** is the "brains" of the hearing aid. It takes the sound it receives and adjusts the sound to amplify important speech sounds as well as filtering out unwanted noise. (To ensure the best in quality, our digital processor is designed and manufactured right here in the **United States**.) Once the processor has amplified the sound, it is passed to the **receiver** (also known as the speaker) which emits a corrected and amplified sound through the **sound tube** into your ear.



The HCX™

Most importantly, your new HCX hearing aids work at a **fraction of the cost** of name-brand hearing aids. In addition to the technical components of the hearing aid, you also have a **volume control** that can be modified with a light touch of the finger. Your new hearing aids come with **3 different audio programs** that help you listen in different sound environments. You will love the Open-fit design, that is so light you probably won't even feel that you are wearing your hearing aids – you'll just be hearing clearly!

You can spend thousands for a high-end hearing aid or you can spend **just \$299** for a hearing aid that just plain works (**only \$279 each when you buy a pair**). We are so sure you will love our product, that we offer a **100% Money Back Guarantee - Risk Free** if you are not satisfied for any reason. It's time to get great digital technology at an affordable price!

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PRESIDENT BARACK OBAMA

ON HOW TO WIN THE
FUTURE



QUESTIONS & ANSWERS WITH *POPULAR SCIENCE*

Along with running the free world, President Barack Obama has spent the past seven years guiding U.S. science and technology policy. The initiatives and goals he puts in place—in clean energy, space, medicine, education, nanotechnology, and more—help direct research, which in turn directs the future. With one year left in the Oval Office, the president talks about what he's achieved, what's left to do (a lot), and why being a nerd is one of the best ways to serve your country.

BY CLIFF RANSOM

PHOTOGRAPHY BY
F. SCOTT SCHAFER



PS: You have been a very pro-science president. Why do you see science and technology as being so important?

BO: Science and technology helped make America the greatest country on Earth. Whether it's setting foot on the moon, developing a vaccine for polio, inventing the Internet, or building the world's strongest military, we've relied on innovative scientists, technologists, engineers, and mathematicians to help us tackle the toughest challenges of our time.

In my first inaugural address, I promised that my administration would restore science to its rightful place, and that's exactly what we've done. We've expanded clean-energy research; we've launched major initiatives in advanced manufacturing, biomedicine, and strategic computing; we've increased preparedness and resilience against climate change; and we're training STEM [science, technology, engineering, and math] teachers so every child grows up with the skills they need to compete in the 21st century. Being pro-science is the only way we make sure that America continues to lead the world. Our policies reflect that.

PS: Among your White House initiatives, you've focused heavily on improving STEM education in America. What's your proudest achievement on that front?

BO: There's a lot to be proud of. We now graduate 25,000 more engineers per year from our colleges and universities than we did when I took office. We're more than halfway toward our goal of preparing 100,000 new math and science teachers by 2021. We've secured more than \$1 billion of private investment for improving STEM education, and commitments from college and university leadership to help underrepresented students earn STEM degrees. There's also something that's harder to measure, but every bit as important: all the young people, including minorities and young women, who are more excited than ever about pursuing their passions for STEM.

One of the new traditions I've started as president is the White House Science Fair. We ought to celebrate science fair winners at least as much as Super Bowl winners. And when young people are excited about science, technology, engineering, and math, that's not just good for them. That's good for America. We want the next game-changing industry or life-saving breakthrough to happen right here in the United States.

PS: Do you consider yourself a nerd and, if so, what's your nerdiest pastime?

BO: Well, my administration did write a pretty detailed response to a petition, explaining

why we wouldn't build a real-life Death Star, so I'd like to think I have at least a little nerd credibility built up.

What's remarkable is the way "nerd" is such a badge of honor now. Growing up, I'm sure I wasn't the only kid who read *Spider-Man* comics and learned how to do the Vulcan salute, but it wasn't like it is today. I get the sense that today's young people are proud to be smart and curious, to design new things, and tackle big problems in unexpected ways. I think America's a nerdier country than it was when I was a kid—and that's a good thing!

PS: You also put heavy emphasis on developing innovation and entrepreneurship. How do you make Silicon Valley happen all over the country?

BO: Innovation and entrepreneurship are already happening all over the country. New technologies like cloud computing, big data, and 3-D printing are lowering barriers to entry. And you can now collaborate with partners around the country or across the world,



WHEN YOUNG PEOPLE ARE EXCITED ABOUT SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH, THAT'S NOT JUST GOOD FOR THEM. THAT'S GOOD FOR AMERICA.

practically at the speed of light. So no matter where you live, there has simply never been a better time to launch an idea and bring it to scale in America.

Of course, we're working to make it even easier for entrepreneurs. No matter who you are, what you look like, or what ZIP code you're born into, if you work hard, you should have the chance to go as far as your talent takes you. That's why our TechHire initiative, which works to place more Americans in well-paid tech jobs, has expanded to 35 cities, states, and counties. It's also why we hosted the first-ever Demo Day and Maker Faire at the White House. I'm going to go out on a limb and say I'm the first president to welcome a 17-foot-tall robotic giraffe onto his lawn.

Some of the most inspiring scientists, entrepreneurs, and inventors I meet are also some of the youngest. Elana Simon presented her work at one of our science fairs. At age 12, Elana survived a rare form of liver cancer. She teamed up with one of her surgeons to gather data about her disease from across the country and discovered a common genetic mutation across the samples she collected—all before graduating high school. That's the kind of story we want to see more of, from every part of America. And I have no doubt that, thanks in part to our policies, we will.

PS: Let's talk about more-difficult science: Two of your biggest science initiatives have been to decode the brain and pioneer precision medicine. Why choose these two?

BO: When it comes to precision medicine, advances in technology, data science, and clinical research are already curing diseases that were once thought to be incurable. It's entirely possible that a decade or two from now, treatments would be tailored not just to the disease, but also to the individual patient. We're being careful to protect patient data and to make participants partners in this work. Because if we embrace precision medicine in the right way, the possibilities for better treatments are practically endless.

The BRAIN Initiative is another project whose time has come. Right now, we can identify galaxies billions of light-years away. We can study particles smaller than an atom. But we still haven't unlocked the mystery of the 3 pounds of matter that sits between our ears. I believe that with America leading the way, we can change that. Hundreds of scientists and dozens of universities, companies, foundations, and other organizations have stepped up to help us tackle this challenge.

PS: You've also advocated the development of a private space industry to work alongside and complement government efforts. What is your vision for space exploration and commercialization? Who does what?

BO: I've laid out a vision for space exploration where our astronauts travel out into the solar system not just to visit, but to stay. To build a sustainable human presence

in space, we'll need a thriving private-sector space economy. I see the expanding space industry as an addition to, not a replacement for, the extraordinary work of NASA. With industry taking over tasks like ferrying cargo and crew to the International Space Station, NASA can focus even more intensely on the most challenging exploration missions, like landing astronauts on Mars or learning more about Earth and the rest of our solar system.

As we set our sights toward other planets, we can also create good jobs here on this one. American companies have begun to reclaim the lucrative market for launching commercial satellites. That's just one example of the way that a growing space economy can help American workers succeed.

PS: If you were to end up on Mars, who would you want as your companion: Mark Watney from *The Martian*, or Ellen Ripley from *Alien*?

BO: As long as it's a hypothetical question, can't I pick both? If I've got Matt Damon growing potatoes and Sigourney Weaver taking care of any unwelcome intruders, I like my chances.

PS: It's been barely two months since a climate agreement was struck in Paris. How do you think the agreement will be remembered 20 years from now?

BO: I believe the Paris agreement can be a turning point for our planet. It's the biggest single step the world has ever taken toward

combating global climate change. When I traveled to Paris at the beginning of the climate conference, I said we needed an enduring agreement that reduces global carbon emissions and commits the world to a low-carbon future. That's exactly what we achieved.

The American people should be proud because this historic agreement is a tribute to American leadership. The skeptics said that taking action to transition to a clean-energy economy would kill jobs. Instead, we've seen the longest streak of private-sector job creation in history. We've driven our economic output to all-time highs, while driving our carbon pollution to its lowest level in nearly two decades.

These kinds of concrete steps helped bring more countries to the table. With our historic joint announcement with China last year, we showed it was possible to bridge the old divides between developed and developing nations that had stymied global progress for too long. And that accomplishment inspired dozens and dozens of other nations to follow our lead and set ambitious climate targets of their own.

PS: Some wonder if the Paris agreement will truly forestall climate change. Do you think it goes far enough?

BO: No agreement is perfect, including this one. But the Paris agreement is the enduring framework the world needs. It will mean less of the carbon pollution that threatens our planet, and more jobs and economic growth driven by low-carbon investment. And it will reduce or delay many of climate change's most damaging effects.

As strong as it is, this agreement will not, on its own, prevent those effects entirely. And so the end of the Paris conference is by no means the end of our work. In fact, now we must begin the next phase: investing in the technologies and unleashing the innovations so we can continue on the path to meet the targets we've set today. That means our governments, our scientists, our businesses, our workers, our investors—everyone working together to build a low-carbon future and the new jobs and industries that it will generate. And because countries agreed to come back to the table every five years, we'll have the chance to set even more-ambitious targets in the years to come.

PS: What do you see as your administration's greatest achievement when it comes to climate science?

BO: Before you can solve a problem, you have to understand it. That's why we've fought hard to protect the funding for the U.S. Global Change Research Program, a government-wide effort to help us see what's happening in the present so we can better predict the future. Thanks to their efforts, our satellites, aircraft, ships, buoys, and terrestrial-monitoring systems are providing indispensable insights and strengthening the models that tell us what to expect going forward.

My administration hasn't just helped to advance climate science—we've also made good use of the results. We used the most up-to-date insights from climate science as the basis of our national Climate Action Plan. And we've begun to develop accessible climate databases and tools that help governments, businesses, and citizens protect themselves from the effects of climate change that we can't avoid.



President Obama, photographed on January 4 at the White House

PS: What would you say to the few climate-change deniers left in Congress and outside it?

BO: Fifteen of the planet's 16 warmest years have come in the first 16 years of the 21st century. The warmest year yet was 2015. The Pentagon is warning us that climate change will threaten our national security by fostering instability overseas. Here at home, we're seeing longer and more dangerous wildfire seasons, coupled with devastating droughts. Last year I visited Alaska, where towns are literally being swallowed up by rising sea levels. Miami now routinely floods at high tide.

So this debate is over. The question now is what we do about climate change because there is such a thing as being too late. And I think that regardless of their party, if candidates for elected office want to resign your children and grandchildren to a world that's broken beyond repair, then there's simply no way they deserve your vote.

PS: One last question on climate: Do you think you've done enough?

BO: Well, here's what we've done. Over the past seven years, we have transformed

America into the global leader in fighting climate change. We've set new fuel standards for cars and trucks, invested more than any administration in history in growing industries like wind and solar, taken unprecedented steps to protect our natural resources, and set limits on the amount of carbon pollution that power plants can dump into the air. Most important, we've proved that we don't have to choose between a growing economy and a safer planet for future generations. We can have both.

But in the end, when I think about our efforts to combat climate change, I don't just think about CO₂-emissions levels or degrees of global temperature rise. I think about my two girls, and the grandchildren I'd hope to have one day. I imagine myself pushing a little boy or girl on a swing set, out in the open air, looking up at the sun. In that moment, I want to know that the planet's going to be in pretty good shape. And I want to have contributed to that.

Because that's our goal: to leave behind a better, safer, more prosperous world for our kids and grandkids. That's our most important mission in the time we have on Earth. And after seven years as president, I've never been more confident that together, we'll succeed.

HOW TO

Live Forever*

Want more
birthdays?
Science
can help.

BY BROOKE BOREL

PHOTOGRAPHY BY THE VOORHES

*Or at least long enough to set off a fire alarm





W

We've long been drawn to immortality, or at least a version of it. In the 16th century, Spanish explorer Juan Ponce de León allegedly searched for the Fountain of Youth. Even further back, in Greek mythology, ambrosia granted eternal life. We're still searching for ways to hit the biological pause button, but today's scientists have a more practical approach: They hope to stall aging to prevent the diseases that so often come with it. If they succeed, we'll not only live longer, we will also be healthier and more youthful. Here's what we know now that Ponce de León didn't.

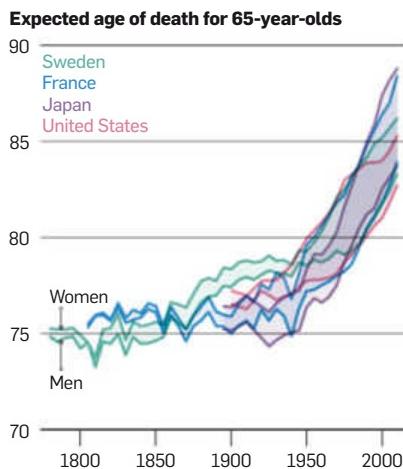
A question of time

Life is destructive. Our environment and our internal functions all wear and tear at our body over time. Evolutionarily speaking, natural selection rewards those who can survive such hardship. So why don't we live forever—why age at all?

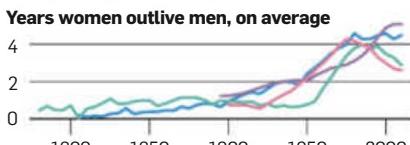
There have been numerous attempts to understand how and why we age—as recently as 1990, the biologist Zhores Medvedev tallied more than 300 possible hypotheses. But according to Steven Austad, a biogerontologist at the University of Alabama at Birmingham, one explanation has risen to the top: “Reproduction is the name of the game. Basically, we age because it’s not in nature’s best interest to perfectly repair our bodies. The main thing is to keep us reproductive as long as possible, and then let our bodies deteriorate.”

The rate of aging in humans and other mammals, Austad says, might be determined by how quickly we have to reproduce before we’re killed off by other factors. In general, the smaller the animal and the more hostile its environment, the shorter it lives. A field mouse, for example, must breed before a hawk snatches it up, and so its organs and immune system don’t need to last 50 years. On the flip side, elephants have few threats, so their bodies can keep going for decades. “In an evolutionary sense,” says Austad, “that is the timekeeper.”

ANNALS OF THE GOLDEN-AGER EXTRA CANDLES FOR THE CAKE



Since 1900, average U.S. life expectancy has risen from 47 to 79. A lot of those gains come from a lower infant-mortality rate: A century ago, 1-in-10 babies born in the U.S. died before age 1, while today that figure is 1-in-170. But longevity gains in later years have also been substantial. This chart shows the expected age of death for those who make it to 65. All four nations shown here have gained about a decade. Women have also outpaced men, a trend Andrew Noymer, a demographer at the University of California at Irvine, ascribes to higher rates of smoking and drinking among males. In the past few decades, men have been closing the gap—meaning more golden years for everyone. **KATIE PEEK**



ANIMAL LESSONS

The average life spans of animals vary wildly from ours, but the mechanisms involved for each appear to be different. “There are multiple roads to longevity,” says Vadim Gladyshev, a geneticist at Harvard Medical School. Identifying strategies that nature uses to alter life span could help scientists figure out how to extend human lives.



BRANDT'S BATS

Despite weighing only about as much as a nickel, Brandt’s bats can live as many as 41 years in the wild. In 2013, Gladyshev and colleagues found changes to genes that alter the animal’s response to growth hormones.



BOWHEAD WHALE

Possibly topping out at older than 200, the bowhead whale is the longest-lived mammal known. In 2015, a team of scientists found genetic variations relevant to aging, cancer protection, cell-cycle regulation, and DNA repair.



NAKED MOLE RAT

Hairless and wrinkled, naked mole rats can live to be 30 years old—many times the life span of other rodents. In 2014, research led by the University of Liverpool found changes in the rat’s genome related to cancer resistance.



OCEAN QUAHOG

In 2006, researchers found an ocean quahog thought to be 507 years old. “That is pretty remarkable when you figure that clams have beating hearts,” says Austad. His lab is looking for the reason its proteins can last so long.



HYDRA

The freshwater hydra seems, under ideal conditions, to be immortal. It also has a seemingly endless supply of stem cells. German researchers have linked a longevity gene, also found in humans, to stem-cell production.

A close-up photograph of a giant tortoise's head and front legs. The tortoise is wearing a festive, multi-colored striped party hat with a shiny, curly blue ribbon at the top. It is set against a solid yellow background.

"Longevity is one of the most exciting areas of research because it really takes into account every aspect of a human being."

—Winifred Rossi, National Institute on Aging



Tortoises typically live well past 100 and might be able to survive even longer. In 2006, a giant tortoise thought to be 255 years old died at India's Calcutta Zoo.

305

Number of known genes that might be associated with aging, of the roughly 20,000 humans possess

Slow aging, stave off disease

SOME EXPERTS on aging think we're at the cusp of a medical revolution. The current model for treating diseases such as cancer, diabetes, Alzheimer's, and cardiovascular disease is to attack each as they pop up.

It's a game of healthcare Whac-A-Mole that might help people live longer but at great cost to their quality of life. A new approach tackles the key risk factor in all these illnesses: age.

"Once you are broken, it is hard to put you back together," says Brian Kennedy, a molecular biologist and president

of the Buck Institute for Research on Aging in California. "If we can target aging, then we can extend human health span, keeping people disease-free and high-functioning."

That would give people more time when it matters most—when they're feeling youthful enough to enjoy it.

Take It from Me, 107-Year-Old Pauline Angleman

I WAS BORN on October 4, 1908. I grew up on a farm with the biggest red barn in western Oklahoma. The farm life is a good life—you eat better, get up earlier, work, and play. You get fresh air and you walk all the time; you're not always riding something. It was a healthier life, I think, than most people live now.

People just need to use their common sense and don't overdo on everything. As my grandma used to say, be like the



woodpecker and use your head. Don't overeat. And lay off all these doggone carbonated drinks. I eat two meals a day and snack a little in the middle. I drink lots of water—it keeps your innards lubricated—and I don't have many wrinkles on my face.

I think it is so important to enjoy what you have. You can kill yourself worrying or being envious or just plain ungrateful. And worry is what brings on illnesses like cancer and heart problems.

Every age has been my favorite. I've had my picture taken so many times, you could paper the White House with it. I have a few aches and pains, but not enough to stop me yet. I have a red Chevrolet Malibu Maxx and my driver's license is good until 2018. Neighbors tell me I'm going to wear out my garage door.

—AS TOLD TO JENNIFER BOGO



CELL SERVICE

Aging starts in a fundamental part of our bodies: our cells. Scientists have identified several processes that all play a role in how cells break down.

CUT SHORT

The end of each chromosome is capped with a protective bit of DNA called a telomere. As a cell ages, the telomere shortens; once it reaches a critical length, the cell stops dividing.

ZOMBIE CELLS

Some cells enter a state called senescence—they stop dividing but resist death, producing inflammatory signals that harm healthy tissues.

TRASH PILEUP

Cells normally perform autophagy, eating up damaged proteins and other debris. But eventually this process jams up and trash overwhelms them.

FAILED ASSASSINS

In order to delete damaged DNA, cells go through apoptosis: programmed death. But some older cells don't actually die, possibly one cause of cancer.

FACTORY HALT

Many organs contain adult stem cells that help regenerate and repair damaged tissues. But as we age, they can cease functioning or dwindle.

SHAKY GENES

DNA constantly faces damage, both from internal glitches and external influences. Over time genetic casualties pile up, and our cells can't repair them.

ENDGAME OVER AND OUT

In 1961, cell biologist Leonard Hayflick showed that human fetal cells kept in the lab divide only a certain number of times before they die. The so-called Hayflick limit seems to play a role in cellular aging, but it's not yet clear how. Some cells, such as cancer, can circumvent the limit and divide indefinitely—possibly via an enzyme that prevents telomeres from shortening.



TIMELINE AGING THROUGH THE AGES

1513 Juan Ponce de León allegedly seeks the Fountain of Youth in Florida.

1750 Average global life expectancy is roughly 27.*

1800s Refrigeration makes it less likely food will spoil—no more deadly meat snacks.

1864 Pasteurization kills pathogens in milk and juice; the world safely drinks up.

1900s Sanitation improves in Europe, North America, and Japan. Goodbye, cholera.

1928 Penicillin kicks off the age of antibiotics, sending deadly bacteria on the run.

1935 Scientists suggest that restricting calories (bummer!) might boost life span.

1949 U.S. formalizes vaccination programs. Kids are free to play with rusty nails.

1950–1955 Average global life expectancy rises to 47.

1961 Researchers say anti-oxidants might extend lives. Good news for vitamin sales.

1970–1975 Average global life expectancy hits 58.

1980s Caloric restriction helps mice live longer.

1988 First gene related to aging is found—in a worm.

1990–1995 Average global life expectancy reaches 65.

2000s Several journal articles nix the idea that antioxidants boost longevity.

2010 As it turns out, some mice live longer with fewer calories; others, not so much.

2010–2015 Average global life expectancy climbs to 70.

2014 New trials on rapamycin and metformin—two drugs shown to extend the lives of mice—begin.

2015 Tourists flock to Ponce de León's Fountain of Youth Archaeological Park. Still no magical water source.

***Source:** *A Concise History of World Population*. Life expectancies after 1750 from the United Nations Population Division.

How to live long & prosper

The advice for living longer hasn't varied much over the years: Eat well, get some sleep and exercise, and cut the stress. Science backs that up.

But exactly how much of each matters to an individual person is still unclear.

"In general, these things are good for you," says Charlotte Peterson, a molecular and cellular biologist at the University of Kentucky, "but some

people benefit more than others. If we could understand that too, it would be a big advance in the field."

But there's no point waiting. Here's what the latest science says and some tools to help you hack your habits.

EAT GOOD STUFF

Science Says: Recent research helps shed light on why certain food staples keep you healthy longer. A 2015 study from the University of Iowa, for example, found there's something to the old adage about an apple a day keeping the doctor away: Ursolic acid, a compound in apple peels, seems to stave off muscle weakness in elderly mice.

Tech Hack: Apps like MyFitnessPal, Nutriro, and Fooducate can help track meals and provide information on ingredients and calories. Or hack your diet with a supercomputer: The Chef Watson app offers recipes for whatever produce is in your fridge.

CATCH SOME Z'S

Science Says: We now know that chronic sleep deprivation increases risk of age-related diseases such as cancer, diabetes, heart disease, stroke, and hypertension. A 2014 study by researchers at the Federal University of São Paulo in Brazil showed that older adults have a higher chance of experiencing sleep disorders.

Tech Hack: Health trackers from Jawbone and BodyMedia include sleep monitors, which record how many times you wake at night and how much time you spend in deep sleep. Mining that data for patterns can link poor sleep to specific habits.

GET MOVING

Science Says: Exercise can decrease your risk of cardiovascular disease, diabetes, and some cancers; it also might help you live longer. So far, scientists don't know what gives exercise its protective quality. But last year the National Institutes of Health announced a \$170 million investment in research that will attempt to find the answer.

Tech Hack: It can be hard to motivate yourself to hit the gym, but the social component of fitness apps can help—particularly if you're competing with friends or family. A 2015 study from the University of Tampere in Finland found that gamification helps boost and sustain regular exercise.

RELAX

Science Says: While short-term stress can help you maintain a healthy immune system, chronic stress increases the risk of heart disease, gastrointestinal issues, and diabetes; it also causes wounds to heal more slowly. Research from Ohio State University in 2013 found that people who care for spouses with dementia, a stressful responsibility, might have immune systems that age at an accelerated rate.

Tech Hack: Wearable monitors like the Spire tracker detect signs of stress and can prod you to take a break. The Bluetooth-enabled Muse headset measures electrical activity in the brain and provides real-time feedback as it guides you through meditation sessions.

HAPPY RETURNS THE DEEP END OF THE GENE POOL

Clues to longevity might lie in the healthiest longest-lived people among us. Boston University researchers have been studying centenarians—people 100 years of age or older—since the mid-1990s. Their findings suggest that most people have the genetic makeup to live well into their 80s if they take care of their health. Centenarians, on the other hand, have the added bonus of protective genes—so far researchers have counted more than 100.

Take Two and Call Me in a Decade

Scientists have discovered several new drugs—or new uses for old drugs—that might help increase health span or life span. They haven't undergone safety testing yet, so don't try at home!

METFORMIN

Used to treat diabetes, metformin helps the body metabolize glucose. It might also slow cellular aging and curb age-related illness. A pilot study on its impact on aging in humans, led by researchers at Albert Einstein College of Medicine, is now underway.

RAPAMYCIN

To prevent organ rejection, rapamycin has been given to kidney-transplant patients for decades. Recent research suggests the drug affects the same enzyme pathway as caloric restriction and so provides the same benefits to longevity (without having to diet). A trial testing the drug in dogs has begun at the University of Washington.

SENOLYTICS

Discovered last year by scientists from Mayo Clinic and the Scripps Research Institute, senolytics kill senescent cells while having little effect on healthy ones. They have been shown to extend the health span of mice.

YOUNG BLOOD

Scientists have long known that stitching the circulatory systems of young mice to old mice can improve the health of the latter. Now they have begun to study this effect in humans: In 2015, the company Alkahest began a trial to learn how young blood affects people with Alzheimer's disease.



7.1 TRILLION

Number of dollars that increasing our health span—the length of time one remains healthy—might add to the U.S. economy over 50 years, according to a 2013 study led by the University of Southern California

QUIZ HOW LONG WILL I LIVE?

The following quiz, based on behaviors of the long-lived Seventh Day Adventists, is adapted from one created by Thomas Perls, a geriatrics specialist at Boston University. It's good, not perfect. "People will write to me and say, 'I love the calculator, but it says I should be dead,'" Perls says. "I say, 'This probably means you had some pretty bad behaviors in the past, but the good news is you have fantastic genes that protected you from them.'"

For the following test, start at 86 if you're male and 89 if you're female. (Sorry, fellas: Women typically live longer than men.)

Do you have a Zen-like attitude that makes it easy to shake stress? If yes, add five years. If no, subtract five.

Do you have family members who've lived to 95 or older? If yes, add 10 years. If no, don't add or subtract anything.

Do you exercise five days a week for at least 30 minutes? If yes, add five years. If no, subtract five.

Are you regularly presenting your brain with interesting or challenging tasks, such as word or math puzzles or active learning? If yes, add five years. If no, don't add or subtract anything.

Does your diet help you maintain a healthy weight so you don't feel slowed down or unwell? If yes, don't add anything. If no, subtract five years.

Do you smoke? If yes, take off 15 years. If no, don't add or subtract anything.

Average global life expectancy at birth—
MEN: 68
WOMEN: 73

A race to the finish

In 2014, Joon Yun, founder of the Palo Alto Institute in California, announced the \$1 million Palo Alto Longevity Prize. Its goal: to “hack the code” of aging.

The first half will go to the first group to restore homeostatic capacity—the body’s ability to stabilize after experiencing stress. “Until midlife, it is so pervasively effective that we don’t realize we have homeostatic capacity until we start losing it,” Yun says.

The hitch is, no one knows how to measure it, and so the prize will use proxies such as heart-rate variability, and award whichever team can get an aging animal’s heart pumping like it’s

young again. The other half of the prize will go to the first group that’s able to extend the life of a mammal by 50 percent.

So far, 30 teams from across the world have signed up to compete, including research groups at schools such as Stanford University and the University of Nebraska Medical Center, and teams from the private sector, such as Volt Health, led by a medical-device designer. The clock is ticking—they have until December 31, 2019 to win.

CAVEAT EMPTOR THE ETHICS OF LIFE EXTENSION

A treatment that extends life span might be tantalizing, but if it’s expensive or inaccessible, it could also make existing healthcare inequalities worse, says Alexander Capron, an expert in health policy and ethics at the University of Southern California Gould School of Law. Life expectancy in the U.S. is already tied strongly to socioeconomic status: People in wealthier counties, such as those surrounding New York City, tend to live longer, while those in the rural South face a shorter life expectancy and poorer health.

BIG-MONEY BET PRIVATE INVESTIGATORS

Some of the biggest names in biotech have joined the effort to forestall aging. They’re well-funded, well-staffed, and largely working in secret.

CALICO

Google founded Calico to develop therapies for age-related diseases. It’s brought firepower to the effort: Calico’s leaders include former heads of drug companies and top-notch experts on genomics and aging. Together with a partner, it has pledged up to \$1.5 billion for research—more than the public National Institute on Aging earmarked for research in 2016.

CYTEGEN

In late 2015, Breakout Labs, a philanthropic venture founded by Peter Thiel, announced CyteGen will be folded into its portfolio of “radical science companies.” CyteGen’s goal: to use a proprietary drug-discovery platform in order to find health-span-increasing drugs that target cell metabolism.

HUMAN LONGEVITY INC.

Geneticist J. Craig Venter took aim at longevity with the 2013 launch of Human Longevity Inc. In October, the company announced its first Health Nucleus facility, which offers personalized analysis of an individual’s genome. That data, in turn, will help build a whole-genome database that feeds research on risk factors for age-related diseases.

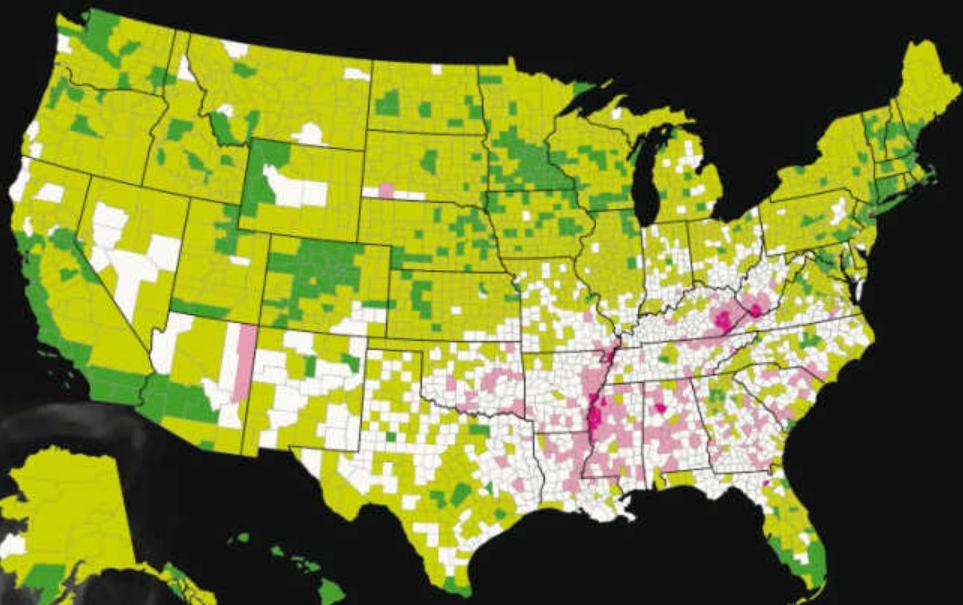


KEY

Colors represent how many years a person born in 2013 can expect to live, by U.S. county.

Average age at death

- 67-71
- 71-74
- 74-77
- 77-80
- 80-84



ANDRE CHUNG FOR WASHINGTON POST/GETTY IMAGES

Who needs a body anyway?



Martine Rothblatt is many things—CEO of biotech company United Therapeutics, founder of Sirius Radio, inventor, lawyer, and medical ethicist—but foremost, she is a futurist. Specifically, Rothblatt believes in transhumanism, or the indefinite extension of human life through technology.

As a result of the growing ubiquity of digital devices, I believe that all of our mannerisms, recollections, feelings, beliefs, attitudes—everything about our lives—will be collected and stored in the cloud. We are creating a simulacrum of ourselves outside our bodies. I call this our “mindfile.”

At the same time, we’re developing ever-better digital assistants that use voice recognition and artificial intelligence. They even have different personalities, like Siri. I call this software “mindware.” And I think the convergence of mindfiles and mindware will produce a seemingly conscious replica of any person—a “mindclone.”

One of the projects my company has been working on is a cognitive enabler for Alzheimer’s disease. An individual beginning to suffer would be able to store enough personality and recollections digitally that, when combined with a camera and voice recognition, he or she can interact with friends and family through the technology—even once no longer able to do so through his or her own brain.

This very naturally leads to the question, how good does an enabler have to be before it is considered part and parcel with the person itself? And when the person’s body finally succumbs, does the enabler claim legal rights?

People have always been afraid of things that are different and weird. But when the weirdness of cyberconsciousness blends with the love for family members, people will see cyberconsciousness as innocuous. By 2030, I believe there will be a social movement of people whose grandmother, sister, or friend has a fatal disease, and who say their mindclones should be legally recognized as a continuation of themselves.

Ultimately, the Internet of Things will enable mindclones to travel, present themselves ever more freely and with greater ubiquity, and even transcend legal death.

—AS TOLD TO MATT GILES

THE BARON OF LOW-EARTH ORBIT

Can ROBERT BIGELOW create a life for humans in space?
By RYAN BRADLEY • Illustration by DIEGO PATIÑO



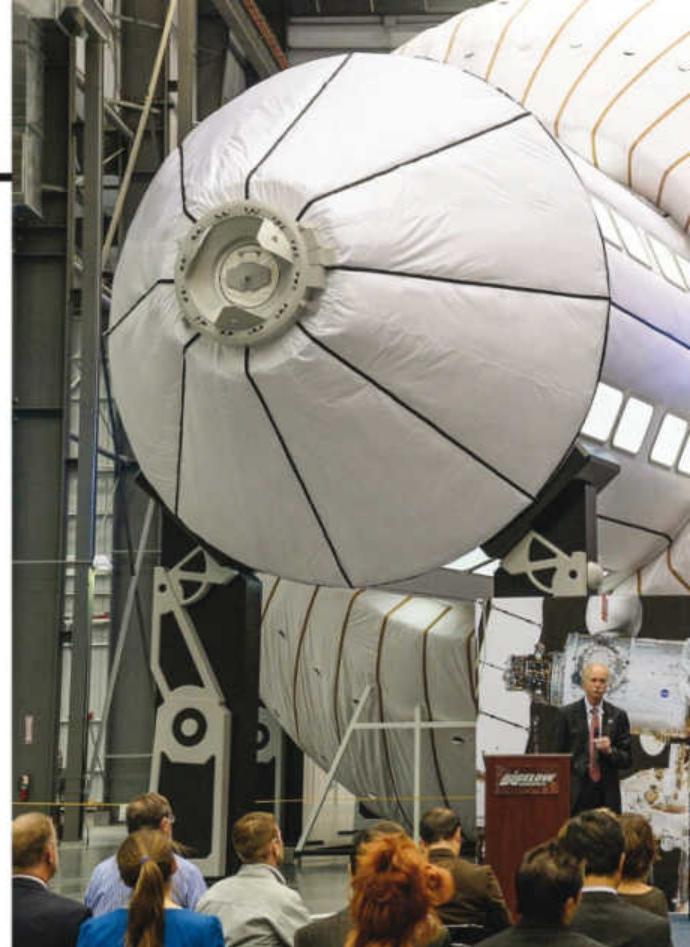


TURN DOWN SKYWALKER WAY, then make a left on Warp Drive. A hangarlike facility is there, huge, as a hangar should be. Inside, a tall mustachioed gentleman in a baggy gray pinstriped suit stands idly. He owns the facility and everything around it. He also owns the Budget Suites of America a few miles away, down near the Las Vegas Strip. That's just part of his empire, that budget hotel, along with a whole chain of others scattered across the Southwest.

But we're not here to talk budget hotels. We're here to talk about the future, and a different kind of accommodations entirely: one that can be folded up, bundled onto a rocket, shot into space, expanded, and lived in. We're here because Robert Bigelow—low-key billionaire, space entrepreneur, avowed believer in extraterrestrials—has invited us into this warehouse to show off his blow-up space home. There are doughnuts and coffee. Soon, lunch will be served. But right now Bigelow is ambling up to a podium, where he begins to scold us.

"You laughed at me," he says to the crowd in his North Las Vegas headquarters. "When we said we would build an expandable system and place it on the International Space Station in two and a half years, you laughed," he says. "It's been two years and a quarter." He pauses, letting it sink in—that he's ahead of schedule—then lets loose a smile, wide as the West. "And here we are."

Here we are: NASA officials, JAXA officials (that's Japan's space agency), media, and Bigelow Aerospace employees. Before Bigelow began his speech, I'd spoken with several of those workers. Dressed in thin white jumpsuits, they stood inside a roped-off area surrounding a pedestal, on top of which sat a refrigerator-size object, swaddled in a gray Kevlar-like material and shaped like an upside-down mixing bowl. This was the



BEAM—the Bigelow Expandable Activity Module—the future of space habitats.

According to the jumpsuited workers, none of whom spoke louder than a reverent whisper, the BEAM would soon travel to the Kennedy Space Center in Florida where eventually—within months or perhaps a year—it would find a berth on a SpaceX Falcon 9 rocket bound for the International Space Station. At the ISS, a robotic arm would reach into the arriving SpaceX Dragon capsule, grab the BEAM, and attach it to the station's Tranquility node. Astronauts would then send a command releasing compressed air into the BEAM. As the BEAM becomes pressurized,

it expands until the module grows to 10.5 feet wide and 565 feet cubed. Not large but not small either. Imagine an eight-person tent or a studio apartment in Manhattan. All told, the expansion will take

**"YOU LAUGHED AT ME," ROBERT BIGELOW TELLS THE CROWD.
"AND NOW HERE WE ARE."**

four and a half minutes. Then, the real work begins.

For two years, the astronauts aboard the ISS will try to determine if the BEAM, or some larger version of it, could be habitable over the long term. They will determine leak rate, measure radiation, and examine the thermal control inside the empty module.



Billionaire Robert Bigelow (above and inset) unveils his expandable modules.

They'll see how the module's soft walls stand up to the bumps and bruises in space. And they'll do their best to figure out just what an expandable structure orbiting Earth at about 5 miles per second feels like—an impossible thing to know until it is up there.

Intuitively, expandables make sense. They pack down, weigh less, and in just about every way mitigate the very high costs associated with breaking free of gravity. The BEAM cost just \$25 million to develop (in part through a \$17.8 million NASA contract) and could cost about \$150 million to launch. Compare that with the (admittedly much more complex) ISS, which cost an estimated \$100 billion, and was assembled over the course of a decade and a few dozen launches. But until the results of this test run come in, no one can say for sure if crewed expandables are indeed as good in practice as they seem to be on paper.

For argument's sake, say the BEAM works. Say everything checks out just as Bigelow thinks it will. What then? He will possibly send a few more pods up to expand the ISS; he's already working on a stand-alone craft. But he also has a more ambitious plan.

Once Bigelow has finished scolding the crowd and detailing the BEAM's upcoming mission, he opens the floor to questions. Someone up front asks how Bigelow Aerospace might fit into a manned Mars mission. He's not sure, he says. Then adds, cryptically,

"We are more focused on the moon." There is no follow-up. He just lets it lie. And so does everyone else—again dismissing what seems too fantastic to be real, though there are no chuckles this time.

As the crowd disperses, I sidle up to Bigelow. Despite the suit, he has the faintly rugged look of an old cowboy. He's sitting slumped in a small plastic folding chair on the small stage, surrounded by a few handlers, and looking worn out. He offers his hand indifferently, but when I ask about his moon plans, he straightens in his chair and leans forward. He drops his low voice even lower, as if letting me in on a secret.

The BEAM, he says, is much more than a simple proof of concept. "It's a first step...toward a permanent settlement on the lunar surface." He sees many similarities between the ISS test run and an eventual lunar mission. "Both would do something unique, in a unique place that has international interests, and would require a lot of partners—governmental and nongovernmental." The BEAM launch, he says, "is not just a stunt—and neither are our moon plans."



BACK IN THE MID-1980S, Bigelow noticed a change happening in the desert Southwest. The area, deemed scarcely habitable, was growing quickly. Businesses were sprouting up, and visitors needed easy, affordable places to stay. To build his empire, Bigelow bought land cheap so he could pass along any savings to customers. He also made his hotels as convenient as possible—set right off the highway. He held onto nearly everything he bought, then sold a bunch of property when everyone else was buying like crazy, just before the market imploded in 2008. His fortune, already vast, grew vaster: His real estate investments alone are estimated at about \$700 million today.

Bigelow now sees a similar change happening in another scarcely inhabited and inhospitable place: space. For a decade private business has been taking over access to low-Earth orbit (LEO), shuttling cargo and soon astronauts. See SpaceX and Orbital ATK as exhibits one and two. As those launches become more frequent—and as the ISS continues to rent out berths to space travelers and bench time to private businesses for zero-gravity experiments—the competition for floor space will only increase. Eventually businesses will set up their own labs and stations, and government-backed space agencies will push beyond LEO into cislunar space, the region between Earth and the moon. The next logical stop is the moon, then perhaps Mars. And then who knows? All Bigelow can be certain of is that such development requires people, and people need places to stay.

That's where his expandables come in. NASA had pursued a similar idea in the 1990s in a program called TransHab, for Transit Habitat. The idea was to build an inflatable craft, cheaper than the ISS, to be used en route to Mars. NASA even designed one, complete with a multilayer shell of insulation and

THE (BLOW-UP) ROAD TO A MOON BASE

Sometime within the next year or so, an expandable pod built by Bigelow Aerospace will travel to the International Space Station—one small step toward the company's goal of building a base on the moon. Here's how it aims to get there.

BEAM (BIGELOW EXPANDABLE ACTIVITY MODULE)

The first step is to prove an expandable pod makes sense in space, that it works better than typical, rigid space habitats. BEAM is a 13-foot-long test pod that SpaceX will haul to the ISS. Once there, it will expand and remain attached to the ISS for two years as crews test it.



B330

The next step is an expandable, full-scale habitat. The six-person, 31-foot-long B330 (it has 330 cubic meters of internal volume) is a bigger, better BEAM. But this one features thrusters, to maneuver in orbit, and stand-alone-life support systems.



OLYMPUS

A colossal craft, the Olympus prototype offers 2,250 cubic meters of volume when pressurized, making it twice as roomy as the ISS. In renderings, it often holds lunar landers—to ferry crew to and from the moon. The problem: No rocket yet exists to carry Olympus into space.



MOON BASE

Once expandables like Olympus can regularly reach the moon's orbit, the problems remaining have largely been solved. In renderings for a moon base, the structure looks like several B330s joined together. NASA had envisioned its own space habitat in the 1990s and early 2000s. Bigelow bought the rights and developed the technology.



meteoroid-debris protection, but Congress cut funding in 2000, so the program was scrapped. Developing a new space station while still running and building the current one didn't sit well, politically. Bigelow thought he saw something they didn't, so he bought the rights to the TransHab technology for dimes on the dollar—the craft's design, the patents for the layered inflatable walls, everything. He then set out creating what he calls "a turnkey solution to space habitation." Cheap and convenient, same as ever.

For a hotel tycoon, new real estate often yields new opportunities. Low-Earth orbit, and all the private space habitats it could someday support, appears promising, at least in the midterm. Even so, there is no piece of real estate more compelling to Bigelow than the moon. Unlike space, the moon has resources. There are deposits of helium-3 for nuclear fusion, which the Chinese are already reportedly planning to mine. There is water in the form of ice, which can be melted and purified for drinking or broken down into hydrogen fuel. The moon is also located outside of Earth's gravity well. For space agencies looking to make runs to Mars or elsewhere, it is an ideal departure and refueling point.

Perhaps most compelling is that Bigelow doesn't see any real competition in building a moon base. NASA isn't all that interested in a permanent moon colony, and it has little in the way of future moon exploration plans. Jason Crusan, who leads NASA's Advanced Exploration Systems Division (basically a venture-capital fund for space-focused businesses, including Bigelow Aerospace) says he can imagine a future where flights travel between Earth and the moon on a regular basis. But rather than NASA taking the lead, he expects others to. "We want to get to Mars," he says. The moon is just a means to an end.

For Bigelow, the challenges of building a functioning base on the moon, while massive, appear far from insurmountable. A recent study, partly commissioned by NASA (put out on the 46th anniversary of the first moon landing), found that the costs associated with returning humans to the moon could be much cheaper than previously imagined—90 percent cheaper, in fact, or closer to \$10 billion versus the previous estimate of about \$100 billion. And setting up a moon base might run about \$40 billion. Much of the savings comes from using the moon's resources *in situ*. "You take what the moon gives you, and move away from things that have to be brought up from Earth: water, fuel, protection from radiation," says George Zamka, a former astronaut and current director at Bigelow Aerospace.

A moon colony is a far cry from the BEAM. But the success of BEAM is critical if a colony is to happen. And that's why Bigelow invited a bunch of NASA officials to his warehouse. He would need NASA's

permission if he ever planned to send further expandables to the ISS and to access its astronauts. NASA, meanwhile, needs proof that expandables are viable habitats, and that Bigelow is the guy to make them.

This is all part of the process, as Bigelow sees it. He's smart enough to know that space habitats need to move slowly for everyone to accept them. But he doesn't have to sit on his hands for two years to learn of BEAM's results. Far from it.



AS BIGELOW TALKS, I stare at the massive structure hanging beyond the stage. The prototype space station, Olympus—formerly called the BA2100—is 41 feet wide and about 60 feet long. It nearly fills a wing of the hangar: three stories, a dozen rooms, with docking bays on each end, to string multiple crafts together. On its own, the Olympus offers more than two times the interior space of the ISS, about 2,250 cubic meters when expanded.

Were it already in space, the Olympus could be docked with a propulsion unit, providing a crewed station in LEO, in lunar orbit, or a point in between. It could also provide a habitat for a trip to Mars. All of which are part of its ultimate purpose. For now, that purpose will remain unfulfilled. It is so massive that, even deflated, no rocket exists that could haul such a large payload into orbit. Bigelow keeps the Olympus front and center for inspiration, a symbol of all that's left to be done.

What's not on display today is Bigelow's follow-up to BEAM, the B330, a fully livable habitat that is well underway. According to Zamka, the craft is designed to fit a crew of six comfortably, has walls about 18 inches thick, layers of insulation, and protection from micrometeorites. It boasts solar and thermal radiator arrays, semiprivate berths, a zero-G toilet, four windows, two sets of control thrusters, and will be able to link up with other spacecraft for docking, towing, or tugging. Bigelow engineers are working on avionics systems for orbit, docking, maneuvering, and boosting beyond LEO into cislunar space. This past May, the company announced it was looking to fill upwards of 100 new positions to build those systems out for a (very optimistic) launch date in 2018.

B330 is much more complex than BEAM. It's not a demonstration pod but a full-fledged expandable spacecraft, capable of sustaining human life on its own. Many of its life-support and comfort systems will be forerunners for a lunar base.

Zamka told me many of B330's most daunting problems have been solved, not solely by Bigelow but with help from NASA. What might still hold up the launch, he said, would be finding a crew,

and a rocket capable of carrying it. At about 43,000 pounds, B330 weighs roughly twice what the Russians or SpaceX can lift. That problem might be temporary, though. Two heavy-lift rockets are coming online shortly: SpaceX's Falcon Heavy, due to launch later this year, and NASA's SLS (for Space Launch System), which will debut within the decade.

That's not to say those rockets ensure B330's success, or even its liftoff. As with all things in space, nothing is certain. And

there is plenty of dissent. Bigelow's critics say he's putting the cart (the craft) before the horse (the rockets), that he's overstepping with his lunar property plans, and that he's letting his belief in the future and value of the moon base get the better of him.

But Bigelow, more than practically anyone, is remarkably comfortable forging ahead in the face of disbelief.

He's seen the impossible happen more than once, after all. As a boy he heard an atomic bomb rumble across the desert beyond Las Vegas. He saw the flash of light. As a man, he built his long-stay empire out on the same barren desert, deemed nearly worthless at the time.

Perhaps because of that, because he's confirmed that the world is surprising and sometimes not what it seems, he's willing to chase ideas that no one else does. In the 1990s, he started the National Institute of Discovery Science for investigations into the paranormal. He bought a ranch in Utah known for UFO sightings and "skinwalkers"—werewolflike creatures that were said to have attacked cattle. The ranch house featured a hallway with a closet that locked from inside. His beliefs can seem silly. But explaining them he is frank and open, as if he's too wise and successful to feel embarrassed about much of anything anymore.

At the end of our conversation, Bigelow's handlers close in, telling him he has more hands to shake. As he steps from the stage, a man in a tie-dye T-shirt and flip-flops, holding a video camera, corners him. "So you believe in aliens," the man says, then launches into a monologue about the mysticism of the desert and extraterrestrial visitations. Bigelow patiently waits him out. "You simply can't know unless you're out there," Bigelow says, then he tells a story he's repeated many times. His grandparents were driving through a desert north of Las Vegas when they saw something otherworldly: a glowing ball of fire in the sky, hurtling toward them, its light taking up their whole windshield.

They told their grandson this story, and ever since he's believed. Intelligent life is out there, he says. He is certain of it. Sure, believing in aliens feeds the doubters, leads to more criticism, makes him the butt of jokes. But Bigelow doesn't worry about that. For him, belief in the impossible—whether aliens or hotels in space—is part of life out here in the desert, or one day out there, on the lunar surface. It always has been. To succeed, you have to prove everyone wrong. You have to get there first.





The War of Social Media

ISIS goes viral—and the world

W

hen the militants of the self-proclaimed Islamic State (also known as ISIS, ISIL, or Daesh) descended on the Iraqi city of Mosul in June 2014, they didn't just march into town—they simultaneously launched a Twitter hashtag campaign, #AllEyesonISIS. It was blitzkrieg with a digital-marketing strategy.

Within hours, images of ISIS barbarity spread throughout the Arab world, sowing fear among Mosul's residents and its defenders. The social-media campaign gave an air of inevitability to the looming seizure of the city, and to the atrocities that would follow. Despite the fact that they outnumbered the attacking ISIS forces by 15-to-1, the Iraqi army units defending Mosul disintegrated and fled. A militia of roughly 1,500 ISIS fighters captured a city of some 1.5 million people.

From its start, social media has been integral to ISIS's rise. It allows the group to raise its prestige among terror organizations, and to overtake older jihadist competitors like al-Qaeda. It serves to coordinate troops and win battles. And it allows the group to administer territory it controls.

Now ISIS is using social media to expand its war far beyond its borders. What started with the choreographed execution video of journalist James Foley, blasted across the Web through an army of dummy Twitter accounts, has now morphed into something more devious and distributed. Rather than calling followers to the front lines, ISIS's social-media strategy cultivates them at home in the U.S., Europe, Africa, and Asia. And it can use those followers to devastating

BY EMERSON BROOKING
AND P.W. SINGER

effect, whether sending gunmen storming into the Bataclan theater in Paris last year or inspiring an American citizen and his wife to massacre 14 co-workers at a holiday party in San Bernardino, California.

In the idealistic and early days of the Internet, many Silicon Valley pioneers thought that in creating a more connect-

ed world, they might also create a more peaceful one. The reality is more complicated. Global connectivity has brought many new opportunities, undoubtedly, but it has also bred a new generation of threats. A decade ago, it would have been unthinkable that a militant in Syria might become pen pals with a lonely teenager in small-town America. These sorts of interactions now keep those at the FBI, NSA, and local law-enforcement agencies awake long into the night.

Yet in war, as in nature, every action has an opposite reaction. Over the past two years, many new forces have marshaled to engage ISIS in this war of social media. The United States has launched a constellation of social-media accounts to battle ISIS misinformation. U.S. spies map ISIS networks through what they reveal of themselves online (one U.S. air strike was even guided by an oversharing jihadist). Outside government, social-media companies have increasingly revised their own systems and terms of service in an effort to mop up terrorist accounts before they spread, as with Twitter's recent ban of all "indirect threats of violence." Hackers and independent activists also play an increasingly important role. Many associated with the hacking collective Anonymous, for instance, have taken to patrolling the darker places of the Internet, waging their own private fight to take down ISIS content wherever they find it. Some of them even named a single day, December 11, ISIS Trolling Day, an event dedicated just to making fun of the group.

So far, there is only one certainty in this fight. What ISIS has discovered—this very weird, effective new way of war—is not a novelty or a one-time thing. ISIS may have been the first to wield this potent mix of social media, terror, and war, but it will not be the last.

fights back.

How ISIS Uses Social Media as a Weapon

Rather than a centralized master plan with a defined leadership, the ISIS social-media campaign is a kaleidoscope of distributed efforts. The group was originally built around seasoned veterans of the Iraqi insurgency, who were then joined by a new generation of millennial recruits. A November study by the New America Foundation found that the average age of Westerners who travel to join ISIS is 24—they've grown up with Facebook, Twitter, and Instagram. Working together, these battle-hardened jihadists and social-media-savvy recruits have developed a loose framework that turns social media into a potent weapon of war.



REASSURANCE



"DOCUMENTARIES"

Using a captured Western television journalist, ISIS staged a series of "investigative" reports. Geared toward potential Western recruits, the videos are in English and have tried to portray the attractiveness of life in the Islamic State.

PRESS RELEASES

Like any business or government agency, the Islamic State churns out a feed of regular announcements via social media that gives the appearance of normality: In one, it announced the grand opening of a children's hospital.



INSTAGRAMMING THE CALIPHATE

Many social-media accounts exist to highlight the lighter side of life in ISIS, trying to build its online image. The most bizarre might be "Cats of Jihad," which gave ISIS fighters a chance to pose their cats with guns on Instagram.

CHOREOGRAPHED VIDEOS

Early on, ISIS became known for its slickly produced videos of foreign-hostage executions. Unlike other jihadist videos, these typically include a script, multiple high-definition camera angles, and even a graphical intro to set the stage.

INTIMIDATION

VIRAL VIDEOS

ISIS regularly records the executions of large groups of local prisoners in order to intimidate and demoralize the opposing units on the battlefield. The videos are also engineered to go viral, with unusual killings such as immolation, drowning, and even explosive collars, all set to a thundering male chorus.

HASHTAG HIJACKING

Using careful planning and an army of Twitter bots, ISIS militants hijack unrelated hashtags to amplify their message and reach wide audiences. The group shouldered into online celebrations of the 2014 World Cup with an image of a decapitated head. The caption? "This is our football, it's made of skin #WorldCup."



VIRAL MARKETING 101

Part of why ISIS has thrived on social media is that it follows the model of what has worked best for leading online figures and corporate brands. According to Haroro J. Ingram, an expert on insurgent information operations at Australian National University, they are "more strategic-plagiarists than geniuses."

ONLINE MAGAZINES

Dabiq is ISIS's monthly online English-language publication. It has higher production values than many professional magazines. It discusses issues of politics, faith, jihad, and bomb-making. The mastermind of the November 2015 Paris terror attacks was previously featured in a softball interview, asking how he could sneak through Europe as a known jihadist.



TARGETING RECRUITS

ISIS militants cultivate vulnerable recruits with sympathetic messages, and engage them via secure messaging services. Recruiters will occasionally ship gifts to the targets—and sometimes, even an airline ticket. If the recruit cannot travel, they are encouraged to launch terror attacks at home.

Q&A SESSIONS

Holding question-and-answer sessions for potential applicants on Ask.fm and other online boards, ISIS fighters frankly discuss the ups and downs of their jobs.

COORDINATION

CIVIC FORUM BOARDS

Writing on encrypted discussion boards, ISIS militants analyze and plan many aspects of their civic administration and operations.



STREAMING DRONES

ISIS fighters have flown small Web-linked drones above the battlefield, gathering real-time reconnaissance footage as well as video for social-media propaganda.

SECURE MESSAGING

In ISIS-controlled territory, day-to-day conversation has moved to services like Skype, Silent Circle, Telegram, and WhatsApp. Secure battlefield communications are sometimes carried out over encrypted messaging platforms like Kik.

Brand consistency

Just as *Star Wars* branding is as consistent on the big screen as it is on a Happy Meal, so too is the Islamic State's. Its flag is monochromatic, so easy to draw and reproduce, and has two slogans: "There is no god but Allah. Mohammad is the messenger of Allah" and "Mohammed is the messenger of God." The monochrome flag has a long history in Eastern, Arabic, and Islamic tradition, going back to one reportedly used by the prophet Mohammad.

Be intimate

With more than 80 million followers, singer Katy Perry is the queen of Twitter. Her posts are authentic—written like someone in a hurry who has taken a minute out of her day to talk to her friends. By the same token, ISIS propaganda often weaves in raw testimonials from front-line fighters. Militants describe sharing meals and laughing together; they also celebrate comrades who've been killed.

Network

In her 2015 music video for *Bad Blood*, singer Taylor Swift shared the spotlight with 18 other stars, including Selena Gomez, Lena Dunham, and Kendrick Lamar. All benefited from their association with Swift, while she expanded her reach to new fan bases. In the same way, ISIS lets other terror groups swear *bayat* (fealty) to it and weaves them into its social-media campaigns. All of the groups expand their credibility and reach.

Engage

In early 2015, Groupon featured the Banana Bunker, a storage unit for bananas. More than a few lewd jokes followed on its Facebook page, and Groupon's social-media team joked back—to every post. The Banana Bunker sold out. Likewise, ISIS fighters engage using social media. A macabre low came with the tweet, "Suggest A Way To Kill the Jordanian Pilot Pig," before ISIS released a video of their Jordanian captive being burned alive.

If all else fails...troll

Businessman and Republican presidential candidate Donald Trump has mastered a particular social-media strategy: He starts arguments with other high-profile figures, which then draws further attention to himself. Surprisingly, ISIS followers actually welcome debate about their horrible and seemingly contradictory acts (death by fire is banned by Islamic scripture), believing it widens their reach and gives them standing.

What Others Are Doing to Fight Back

With threats mounting, an unusual alliance has begun to fight back against ISIS's social-media war. Governments have launched offices that monitor and refute terrorist propaganda in real time. Companies have set rules of conduct to prevent ISIS from using their products. Community activists have sought to identify and reach out to youth at risk of falling under the sway of ISIS recruiters. And members of the Anonymous hacking collective have hunted and destroyed ISIS websites in the darkest corners of the Internet. Together, this loose coalition has sought to kick ISIS out of the very social-media ecosystem that has helped give it life.



SUPPRESSION



CONTENT MODERATION

Google, Twitter, and Facebook—platforms for free and unfettered speech—revised their terms of service to ban jihadist content. YouTube uses human-rights groups as "flaggers" to identify ISIS content.

TWITTER ACCOUNT HUNTING

Groups of hackers hunt down and report ISIS accounts on Twitter; they claim to have eliminated more than 100,000. They use algorithms to flag these accounts hundreds of times in rapid succession.

DETECTION

Because accounts can be quickly re-created, hackers have written programs to search for multiples of similar-sounding Twitter handles. ISIS militants, however, have responded with programs that automatically hide these.

HACKING

DOXXING

Posing as potential recruits, hackers gather intel about ISIS recruiters, using cyberforensics to identify and locate them. This information is then revealed to the world and passed along to local authorities. One such tip, discovered by Ghost Security hackers, helped avert a July terror attack in Tunisia.

SABOTAGE

Hackers dive into the deep Web, beyond the reach of most search engines, to find and eliminate ISIS recruiting centers and bitcoin donation pages. In one case, the Ghost Security Group (not to be confused with Ghost Security) replaced an ISIS propaganda hub with an advertisement for Viagra and Prozac.

DISTRIBUTED DENIAL OF SERVICE (DDOS) ATTACKS

Hackers use tens of thousands of linked computers (botnets) to overwhelm ISIS websites, sometimes burning out their physical servers.



COUNTERRECRUITMENT

REFUTING TERRORIST NARRATIVES

The U.S. government manages a series of Facebook, Twitter, YouTube, and Tumblr accounts, such as the "Think Again Turn Away" series, to highlight and counter ISIS propaganda and misinformation.

TARGETED ADVERTISING

The Institute for Strategic Dialogue, a British think tank, has used Google search key words (for example, people searching "How do I get to Syria?") to target at-risk users. They are sent instead anti-extremist Web videos that (initially) look like just another piece of ISIS propaganda.

COUNTER-ISIS HACKATHONS

Australia is one of several countries that has launched national hackathons, convening Web developers and Muslim community leaders to create online tools that will help locals resist the group's siren call. Ideas have included cooperative games, specialized social networks for Muslim youth, and even a "Tinder for mentoring."

COUNTERINTELLIGENCE

FORUM INFILTRATION

Government intelligence agencies and hackers both use a variety of tactics to infiltrate jihadist forums. They become "flies on the wall," collecting information on who is recruiting and who is being recruited.

OPEN-SOURCE INTELLIGENCE GATHERING

Researchers comb ISIS social-media accounts to identify who is in the network, and to conduct data analysis on trends and patterns. They are looking for what interests the online community of radicals in order to predict what they'll do next.

FIRSTHAND REPORTING

Brave citizens in ISIS-administered territory launch blogs and Facebook pages to document ISIS war crimes, refuting the group's propaganda of life in the caliphate. It is risky; those caught by ISIS face immediate execution.

PROPAGANDA THROUGHOUT HISTORY

The technologies have changed, but the goals of warfare propaganda have been the same for centuries: Get in the enemy's head, and get vulnerable would-be recruits to fight on your side.

1800s

Leaflets

Inflammatory leaflets helped fuel the 1887 Haymarket Affair, a United States labor protest that led to an anarchist bombing. In 1902, leaflets by the Socialist Revolutionaries in Russia (who would ultimately overthrow the Czarist government) called for terrorist acts against the autocracy, among the first modern uses of the word "terrorist."

1940s

Radio

Underground radio came to prominence during World War II as a way to organize partisan resistance movements, most notably in Nazi-occupied Europe.

1970s

Cassette Tapes

The sermons of Iran's exiled Ruhollah Khomeini spread via audiotape among student protesters in Iran, helping to hurl the nation toward revolution and allow Ayatollah Khomeini to assume the role of Supreme Leader of the new Islamic Republic. As one Iranian official remarked at the time, "Tape cassettes are stronger than fighter planes."

1980s

VHS

When Soviet soldiers were bogged down in Afghanistan, blurry videos of the mujahedeen rebels fighting them spread across the Muslim world. Similar videos emerged from mujahedeen who went on to fight in Bosnia and Chechnya in the 1990s. Emerging terrorist leaders like Osama Bin Laden took to recording their messages on VHS and smuggling them to their followers, who could quickly copy and disseminate them.

1990s

Websites

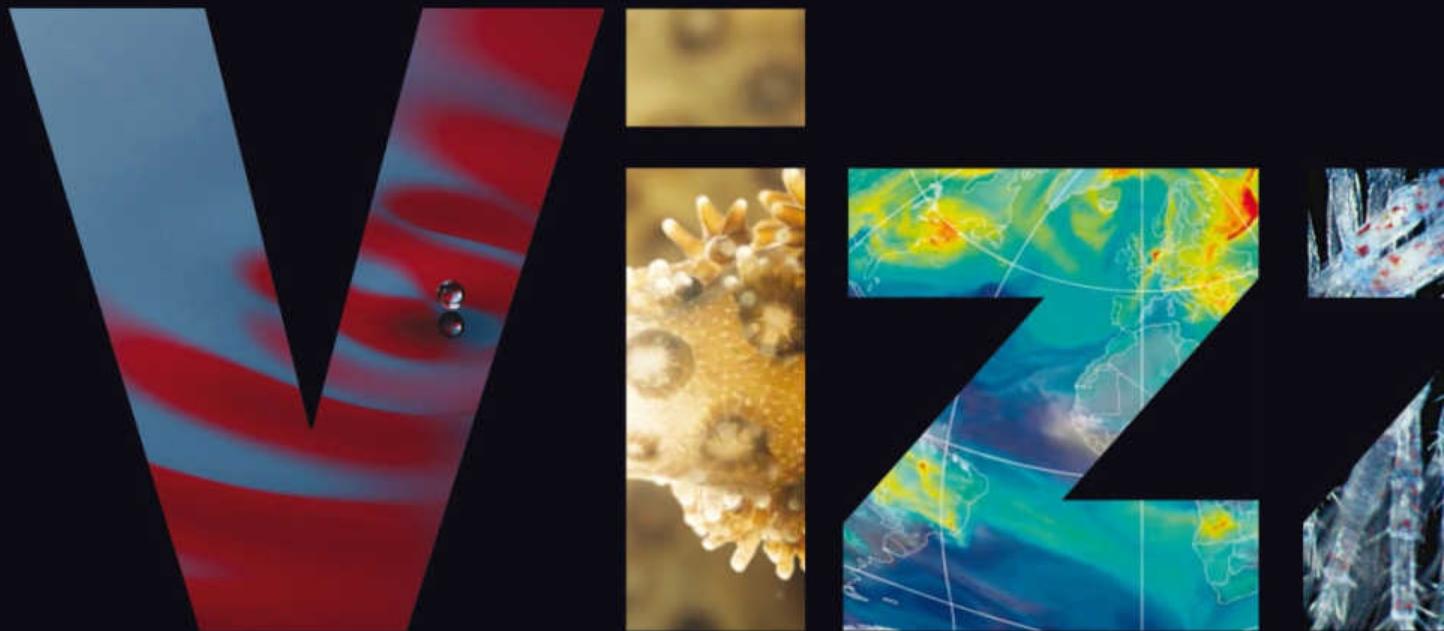
The first jihadist website, the Islamic Media Center, appeared online in 1991. Many more followed. These simple websites provided quick and universal access to jihadist literature everywhere.

2000s

Downloadable Videos

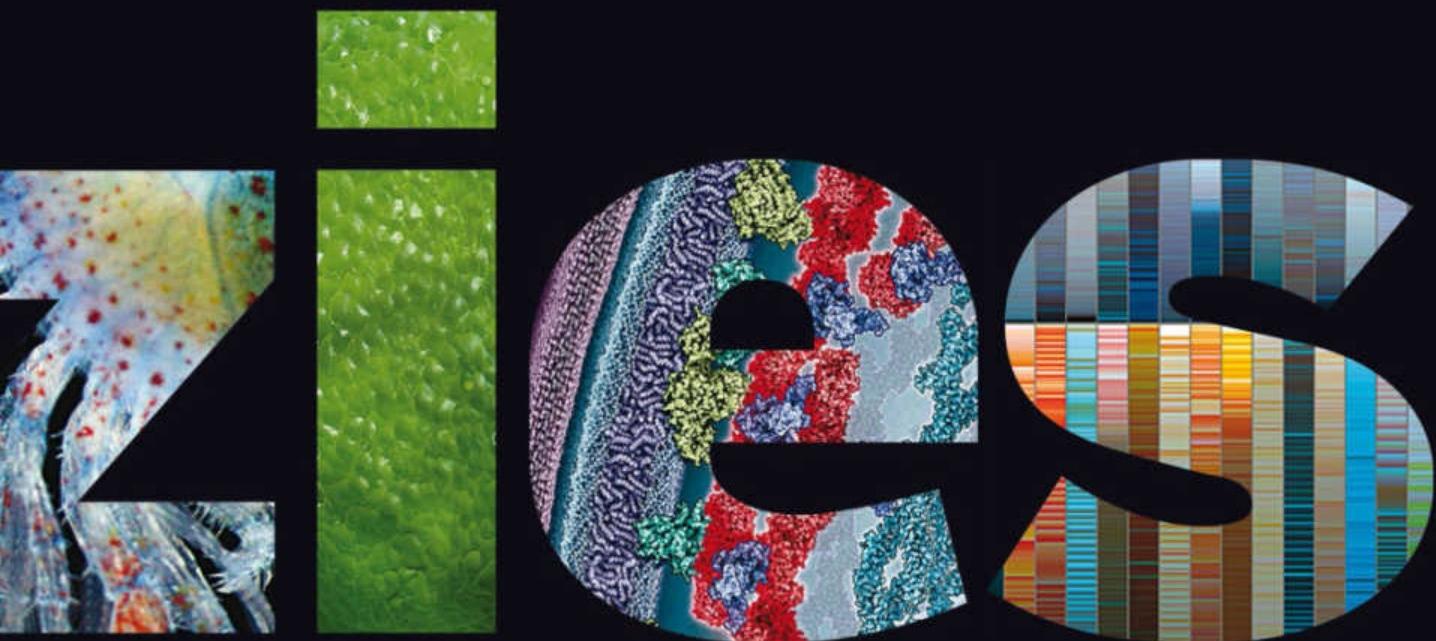
Al-Qaeda released its first online video in mid-2001. It claimed credit for destroying the USS *Cole*, an event that had killed 17 American sailors the previous year. The world of terrorism and technology was set in motion for 9/11 and the Internet Age.

The 2016



The most exciting areas of science often can't be seen with the naked eye because the phenomena are too big or too small, too slow or too fast. That's why we believe it's worth honoring those who use novel techniques—or create exceptional examples of traditional ones—to present scientific ideas visually. So, for the second year, *Popular Science* has teamed up with the National Science Foundation to bring you exemplars of information made beautiful. Congratulations to the winners!

WE PRESENT THE WINNERS OF OUR ANNUAL SCIENCE AND ENGINEERING VISUALIZATION COMPETITION



HOW WE SELECTED THE BEST

A team of experts at the National Science Foundation and *Popular Science* pared hundreds of submissions to 50 finalists—10 in each of the five categories. From those 50, a panel of outside experts picked five winners. Another panel of experts—that is to say, our readers—chose five People's Choice winners.

THE EXPERT JUDGES

David Bolinsky, medical animator and co-founder of e.mersion studios

Martha Harbison, network content editor for the Audubon Society

Eric Klopfer, professor of science education and engineering systems at MIT

Robert Kosara, research scientist at Tableau Software

Miriam Leuchter, editor-in-chief of *Popular Photography*

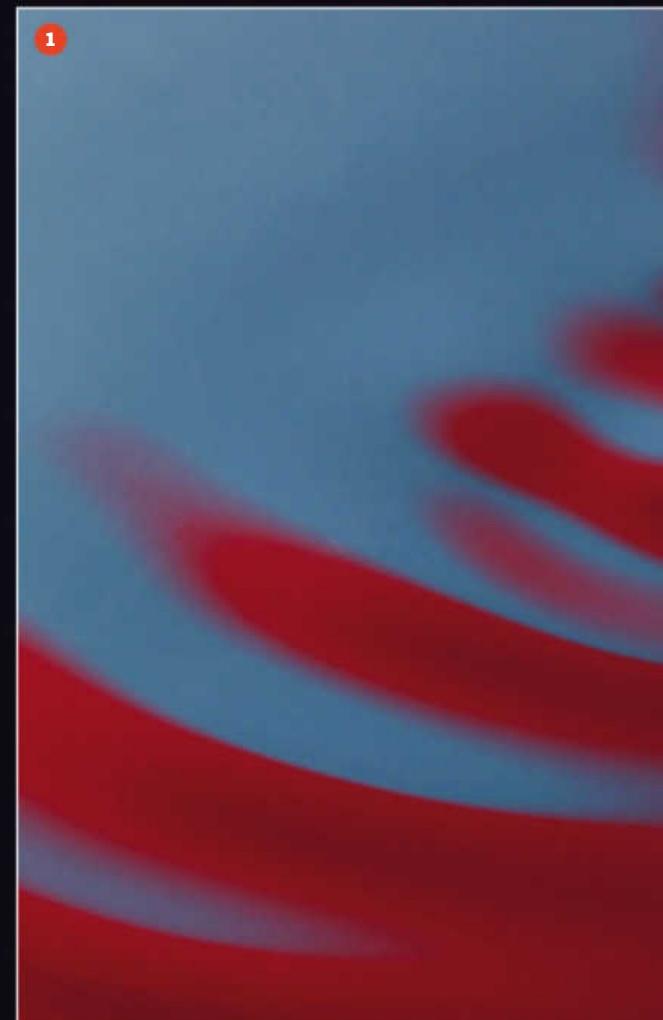
Eleanor Lutz, designer and science illustrator behind *TabletopWhale.com*

Heather B. McDonald, independent biologist and artist

Jan Willem Tulp, head of the data visualization studio TULP Interactive

A PROJECT OF THE
NATIONAL SCIENCE FOUNDATION
AND *POPULAR SCIENCE*



**PHOTOGRAPHY****1. EXPERT'S CHOICE****WALKING IN COLOR**

By Daniel M. Harris and John W.M. Bush

Quantum physics measures movements of the tiniest particles in the universe, which not only happen incredibly quickly and on very small scales, but also defy physicists' intuition. Analogies from the macroscopic world can help scientists visualize quantumlike phenomena more easily. Daniel Harris, then a doctoral student at MIT, turned to a quirky relation-

ship between liquid droplets and a vibrating bath. The vibration stops the droplet from assimilating into the bath, and it bounces across the surface instead. The droplet and the waves it creates mimic some of the statistical behaviors of quantum particles—except they're visible to the naked eye. The photo is one of several hundred Harris took for his doctorate, all snapped with an off-the-shelf camera.

2. PEOPLE'S CHOICE**AMERICAN LOBSTER LARVA**

By Jesica Waller, Halley McVeigh, and Noah Oppenheim

As a master's student in marine biology at the University of Maine, Jesica Waller spent the summer taking pictures of baby lobsters. Increasingly warm and acidic oceans affect many marine species, and so Waller raised thousands of lobsters in the lab—no easy task, since young lobsters tend to eat one another—to see how different climate-change scenarios alter their development. This image of a live three-week-old specimen was one of thousands Waller took. It captures the distinct, delicate hairs on the legs. Since lobsters have very poor vision, they rely on their

leg hairs for sensory tasks such as finding food. Adults have them too, meaning baby and grown-up lobsters alike taste with their feet.

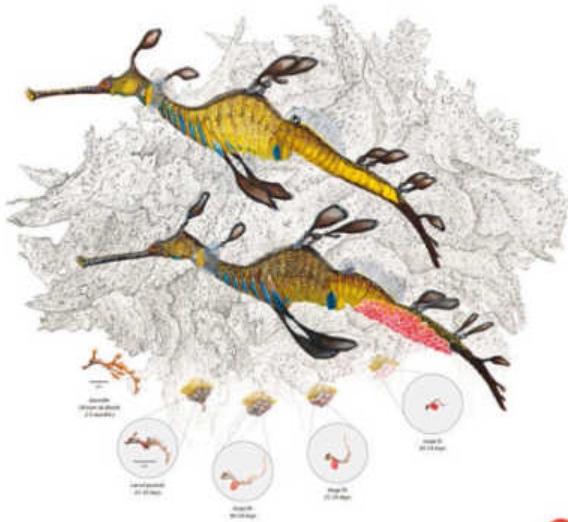
VIDEO***3. EXPERT'S CHOICE AND PEOPLE'S CHOICE****CORAL BLEACHING: A BREAKDOWN OF SYMBIOSIS**

By Fabian de Kok-Mercado, Satoshi Amagai, Mark Nielsen, Dennis Liu, and Steve Palumbi

Corals are a quirky species—they're invertebrate animals built out of genetically identical polyps,



Weedy Seadragon
Phyllopteryx taeniolatus



which collect together into massive underwater reef structures. For food, they rely on a symbiotic relationship with algae, which make sugar and nutrients through photosynthesis. This video, created by a team at the Howard Hughes Medical Institute, envisions a reef seen from miles above the planet. Then, it zooms in to the microscopic structures where the algae live. The animation details how rising ocean temperatures can prompt coral to eject the algae—a process known as coral bleaching. Without their symbiotic partners, bleached coral slowly die.

4. HONORABLE MENTION ENTOMOLOGY ANIMATED EPISODE 1: RIFA MADNESS

By Eric Keller

Though less than a quarter-inch long, fire ants terrify even the largest humans. A brief encounter with a colony can leave a person's body riddled with hundreds of angry, red stings. But freelance digital artist Eric Keller finds them fascinating. He proclaims his enthusiasm in the first episode of his video series, *Entomology Animated*. Viewers see the natural history of *Solenopsis invicta*, the physiology behind their spiteful

stingers, and the biochemistry of the venom. Keller created the video as a labor of love, even down to the background music, which he composed himself. The famed entomologist E.O. Wilson was so impressed, he entreated Keller to make more biology animations. Keller says he's working on it.

ILLUSTRATION

5. EXPERT'S CHOICE WEEDY SEADRAGON LIFE CYCLE

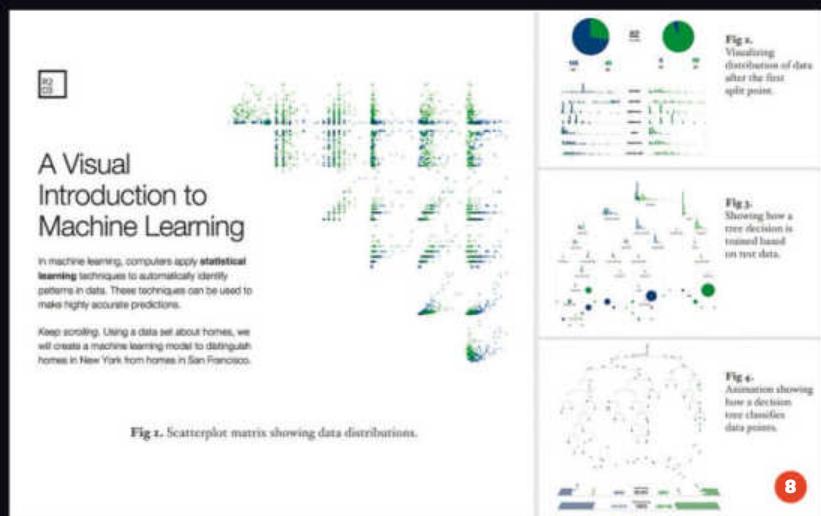
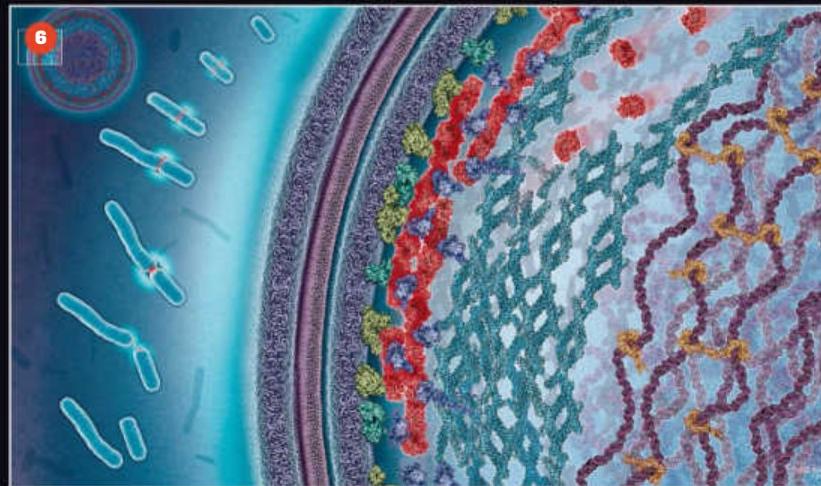
By Stephanie Rozzo

During her time volunteering at the Monterey Bay Aquarium,

freelance science illustrator Stephanie Rozzo helped clean the seahorse exhibit. Over time, she found herself enchanted by their colors and movements. Rozzo knew she had her next illustration subject when one male began carrying eggs (as males of the species do). She rendered an expectant pair of seadragons—native Australian fish closely related to seahorses—in acrylic paint with their seaweed habitat in graphite. The work depicts the species' life stages from embryonic fry through adulthood.

Category continued on next page

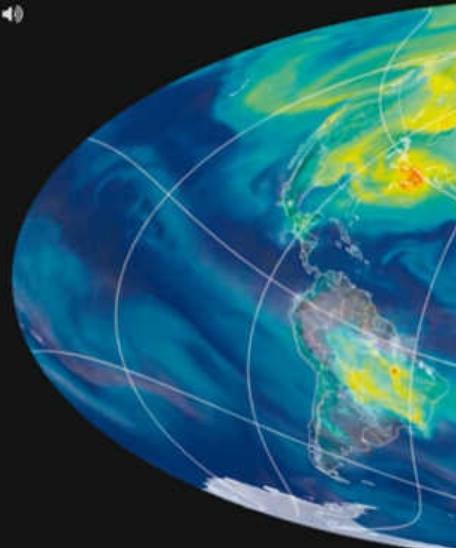
*VISIT popsci.com/vizzies to watch the winning videos.



A Year In The Life Of Earth's CO₂



|| ▶

Carbon Monoxide Column Abundance (1.0e18 molec cm⁻²)

0.0 0.6 1.2 1.8 2.4 3 3.6 4.2 4.8 5.4 6.0

says she hopes the layperson can appreciate the complexity of the microscopic world in the image. Harold Erickson, a cell biologist at Duke University who has studied FtsZ but wasn't involved in the research, called the model "quite an achievement."

INTERACTIVE*

7. EXPERT'S CHOICE
A YEAR IN THE LIFE OF EARTH'S CO₂
By Bernhard Jenny, Bojan Šavrić, Johannes Liem, William M. Putman, Kayvon Sharghi, Aaron

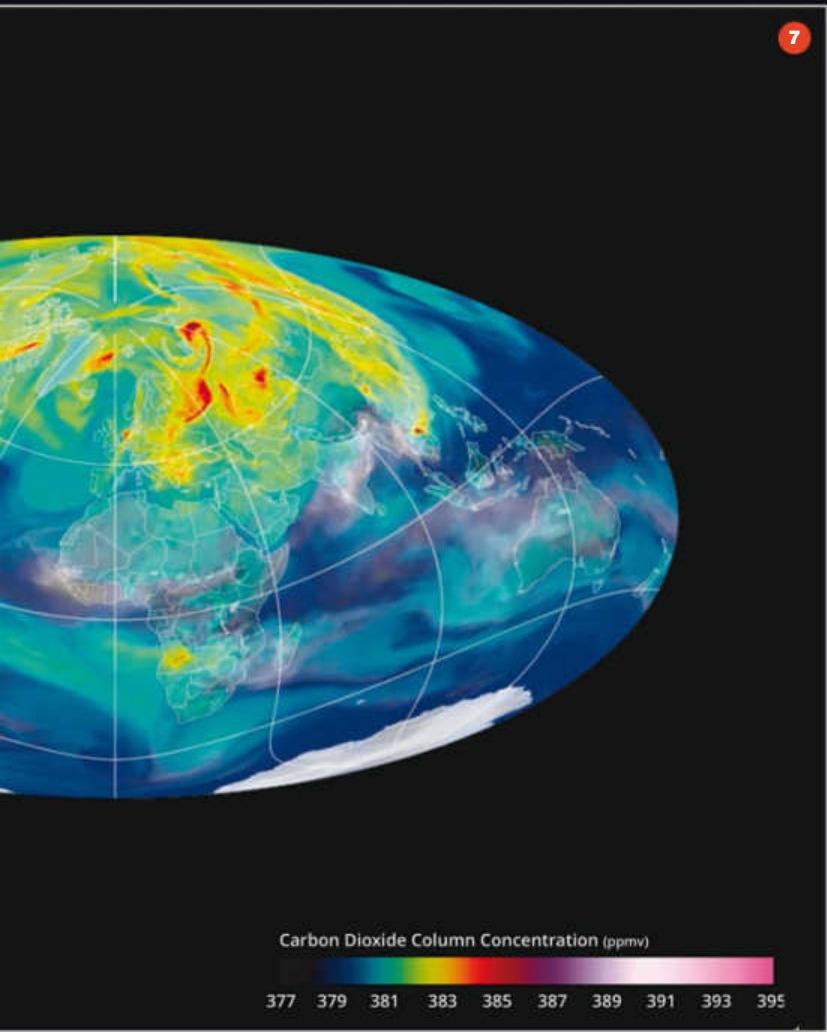
E. Lepsch, and Patrick Lynch

While a professor at Oregon State, cartographer Bernhard Jenny made this visualization, which shows how carbon dioxide travels around the globe. The work builds on research by NASA meteorologist Bill Putman, whose team modeled atmospheric CO₂ flows and created a video of the result. Jenny integrated the video with an interface that allows users to reposition the globe and explore the data themselves. "We wanted to make this video as engaging as possible to illustrate how humans change our planet," Jenny says.

8. PEOPLE'S CHOICE
A VISUAL INTRODUCTION TO MACHINE LEARNING
By Stephanie Yee and Tony Chu

As an employee of a company that provides digital security through machine learning, Stephanie Yee spent a lot of time familiarizing clients with the secret sauce behind her product. So she and her colleague, designer Tony Chu, set out to create an interactive graphic that would do the explaining for them. The pair chose a topic they thought would be intuitive to most people—real estate prices—and created an interactive environment

*VISIT popsci.com/vizzies to interact with these winners.



that builds in complexity as the user scrolls. In the first 30 days, the site got 250,000 page views worldwide. Feedback showed Chu and Yee that experts in many fields could use their interactives. The duo is collaborating with academics to tailor their next set of explanatory machine-learning visualizations to different disciplines.

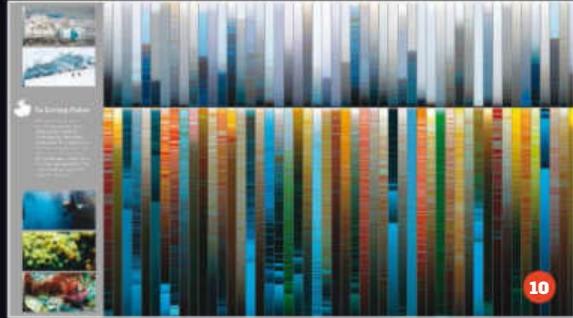
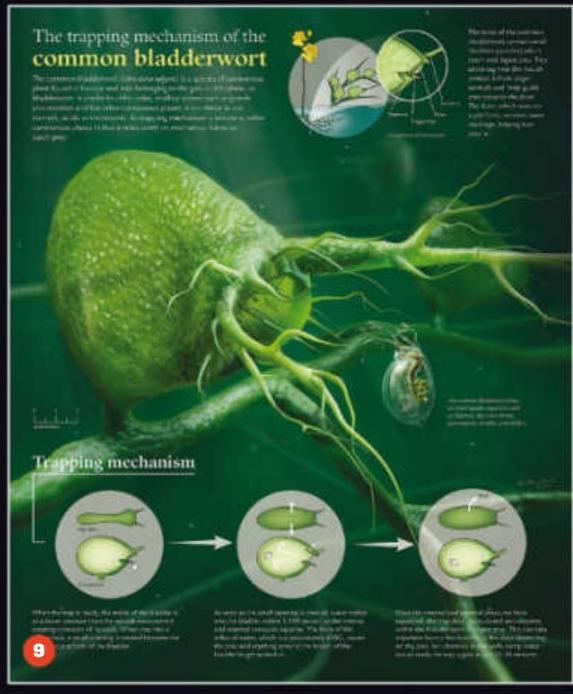
POSTERS & GRAPHICS

9. EXPERT'S CHOICE THE TRAPPING MECHANISM OF THE COMMON BLADDERWORT

By Wai-Man Chan

The common bladderwort is a diminutive aquatic plant with fetching yellow flowers that lives on ponds and lakes in Asia and Europe. But under the surface, it hides a carnivorous secret: 1-inch chambers—or bladders—along its branches that suck in unsuspecting prey. Wai-Man Chan, a graduate student in biomedical visualization at the University of Illinois at Chicago, saw a plastic model of a bladderwort at the Field Museum in Chicago, and says she was intrigued that the tiny, bulbous bladder could contain such a powerful trap. Her poster

7



captures the dramatic moment just before the green monster ensnares a passing water flea, presenting the organism's anatomy in exquisite—and appropriately creepy—detail.

10. PEOPLE'S CHOICE ANTARCTICA: A CHROMATIC PARADOX

By Skye Moret

Even after nine trips to Antarctica as a marine-science technician, Skye Moret is still awed by the sea life that surrounds the icy continent. The waters brim with yellow sea stars, pink sea cucumbers, and

delicate purple octopuses. To show off the vibrancy of the sub-marine environment, Moret compared 50 land and seascapes from above the surface with 50 shallow-water shots from below. She sampled the pixels from each image, and ordered them by hue and value. The resulting visualization hints at the color and diversity in the Southern Ocean. Moret wants to awe viewers but also remind them of climate change's reach. "Life underneath the surface is warming also—it's threatened and vulnerable, and it's typically neglected in the dialogue," she says. 

Fukushima

Five

Years

Later

JAPAN IS STILL CLEANING UP
ONE OF THE WORST NUCLEAR
DISASTERS THE WORLD HAS
EVER SEEN.

STEVE FEATHERSTONE WENT
THERE TO SEE HOW MUCH THEY
HAVE ACCOMPLISHED—AND
HOW FAR THEY HAVE TO GO.

PHOTOGRAPHY BY
MICHAEL FORSTER ROTHBART



I

ON MARCH 11, 2011,
THE MOST POWERFUL
EARTHQUAKE EVER
RECORDED IN JAPAN
STRUCK THE NORTHEAST
COAST OF THE MAIN
ISLAND. THE GROUND
SHOOK FOR SIX MINUTES,
CUTTING ELECTRICAL
POWER TO THE
FUKUSHIMA DAIICHI
NUCLEAR POWER PLANT.

A 50-foot wall of water spawned by the quake exploded over Daiichi's seawall, swamping backup diesel generators. Four of six nuclear reactors on-site experienced a total blackout. In the days that followed, three of them melted down, spewing enormous amounts of radiation into the air and sea in what became the worst nuclear disaster since Chernobyl in 1986.

The Japanese government never considered abandoning Fukushima as the Soviet Union did with Chernobyl. It made the unprecedented decision to clean up the contaminated areas—in the process, generating a projected 22 million cubic meters of low-level radioactive waste—and return some 80,000 nuclear refugees to their homes. This past September, the first of 11 towns in Fukushima's mandatory evacuation zone reopened after extensive decontamination, but fewer than 2 percent of evacuees returned that month. More will follow, but surveys indicate that the majority don't want to go back. Some evacuees are afraid of radiation; many have simply moved on with their lives.

Another town scheduled to reopen, sometime in the next two years, is Tomioka, 6 miles south of the nuclear plant. One night this past fall I drove around Tomioka's

waterfront, which the tsunami had completely wiped out. It was eerily quiet, save for a loud, metallic clap echoing through the empty streets from the direction of an incineration facility. Wild boar scampered through fields where the old train station once stood. And a breeze carried the scent of mold and rot from shops and homes that had been cracked open by the earthquake and gutted by the tsunami. In one shop, a truck had been carried through a display window and deposited on the floor as if it had been deliberately parked there.

During the day, Tomioka, which once had 16,000 residents, is a vast construction site sprawling for miles across residential neighborhoods, commercial districts, and fallow rice fields. Thousands of decontamination workers equipped with little more than shovels strip 2 inches of contaminated topsoil in a 65-foot perimeter around every structure in town. They dump the soil into black decontamination bags, which they pile onto every street corner and empty lot. Some bags have been there so long, they've sprouted weeds. The workers also use dry hand towels to wipe down every single building, from the roof to the foundation, and pressure-wash any asphalt and concrete. It's tedious, exhausting work.

The town allows residents to visit during the day, but special permission is required for overnight stays. When I met him, Kenichi Hiyashi, a broad-shouldered supervisor for a company cleaning up Tomioka, was about to move back to his house on the outskirts of town. Four and half years earlier, when he evacuated with his daughter and parents, radiation levels were 5 microsieverts per hour ($\mu\text{Sv}/\text{h}$). Now they hovered at around 0.6 $\mu\text{Sv}/\text{h}$ —still more than twice the government's long-term goal of

0.23 $\mu\text{Sv}/\text{h}$, and about 15 times the normal background level in Tokyo. Hiyashi had returned to Tomioka, a mildly radioactive ghost town, for reasons millions of suburbanites could appreciate.

"The commute was killing me," he lamented.

Hiyashi took me to see his house, which had been decontaminated just that week. In the driveway, an empty decontamination bag sagged in a steel frame. Bright pink tape marked areas of high radiation: downspouts, faucets, electrical conduit. We walked around the yard, avoiding piles of clean fill that hadn't been raked out yet. The sun was going down over a dark stand of pine trees across the road. Crickets began to stir in the high grass growing beyond the decontamination buffer zone. Hiyashi put his hands on his hips and looked around at the neighborhood of darkened houses.

"Tomioka exists only in name," he said. "It'll never be a town again." I got the sense that Hiyashi, like so many evacuees, would rather be compensated to relocate. Owning a house in a place few want to live isn't much of an inheritance for his daughter.

II.

WHILE THE Japanese government rebuilds Fukushima prefecture, the Tokyo Electric Power Company (TEPCO) is slowly dismantling the Fukushima Daiichi nuclear power plant, a process that's expected to cost at least \$15 billion. Two weeks after I visited Hiyashi, I drove through Tomioka again, this time on a bus with a handful of other journalists headed to the site.

Inside the plant gates, guides wearing white TEPCO golf shirts herded us inside the Entrance Control Building, where some of



Nuclear scientist Ikuro Anzai measures radiation levels near a nursery school in Fukushima City.

the 7,000 employees who now work at Fukushima Daiichi strip out of their protective clothing in front of long rows of lockers. One of our guides said that things were beginning to return to normal, pointing out that workers no longer needed to wear full-face respirators at 90 percent of the site, and also that vending machines were recently installed outside the cafeteria. Given the popularity of vending machines in Japan, this wasn't a stretch.

After a briefing, we were taken to an adjoining building where TEPCO had a special viewing room outfitted with thick, radiation-proof portholes. Carved from a 115-foot coastal bluff in the late 1960s, the Fukushima Daiichi complex has two main terraces separated by a steep slope. From my vantage point seven stories above the upper terrace, I could see the entire 860-acre site, a bustling city of workers garbed in white Tyvek suits. Construction vehicles rumbled down roads between blocks of drab industrial buildings. Before the disaster, much of the plant's grounds were covered in pine trees that served as a bird sanctuary.

"Every time I come here, I'm so surprised," said one TEPCO guide as he stared in awe at row upon row of water tanks below. "Two years ago, it was all flat land."

Half a mile to the east, where the site meets the Pacific Ocean, four of the reactors rise up from the lower terrace: Unit 4 with its trellislike support structure; the stub of Unit 3; the deceptively intact Unit 2, which is the only damaged reactor to still sport its outer shell; and Unit 1, clad in beige panels. The different appearance of each reactor reflected the complexity of decommissioning the site.

"At Fukushima Daiichi, there's no textbook," said chief decommissioning officer, Naohiro Masuda, when I spoke to him at TEPCO's headquarters in Tokyo a week earlier. "There are three reactors [that melted down], and each has a different manner in which the fuel melted. The buildings are damaged in different ways. So we need to think of three different methods to solve this problem." In other words, Fukushima Daiichi has three separate decommissioning projects, not just one.

A reactor like those at Fukushima Daiichi is essentially a sophisticated machine for boiling water. Fission heat



Bags filled with contaminated soil and debris stack up on a site in Naraha.
Left: Workers build a new seawall along Fukushima's coast.

from nuclear fuel rods makes steam that spins a turbine, producing electricity. The steam is condensed, cooled, and pumped back into the reactor core to keep the fuel from overheating, and to make more steam. If water circulation stops, the rods can get so hot that they begin to lose integrity. In a worst-case scenario, they melt like wax candles, and the molten fuel pools up inside the reactor, releasing massive amounts of radiation.

Masuda estimates that decommissioning the Fukushima Daiichi site—removing all nuclear and radiological hazards—will take three to four decades, although he acknowledged that the technologies required to scoop melted fuel out of the damaged reactors don't even exist yet.

"Engineers are studying the problem," he says, "but we don't think that there's *no* way to remove the fuel. There's huge risk involved. If you make one small mistake, it might cause a huge problem for the local people, or even worldwide. We have to be aware of that possibility."

To get a closer look at the reactors, we donned anti-contamination gear: safety helmet, dust mask, goggles, two pairs of latex gloves, one pair of cotton gloves, long-sleeved undershirt with breast pockets to hold a dosimeter (a device the size of a flip phone that measures the amount of radiation a person absorbs), disposable pants, two pairs of socks, Tyvek suit, rubber boots, disposable

boot covers, and masking tape to seal the shirt cuffs. All of these precautions were supposed to keep radioactive contaminants from getting inside our lungs and on our skin. It provided no protection whatsoever against gamma radiation. A TEPCO handout informed us that our dosimeters were set to beep in 20 μ Sv intervals. Properly clothed, we clambered aboard a bus upholstered in thick plastic and duct tape.

FATAL RADIATION LEVELS MAKE IT
IMPOSSIBLE TO SEND INSPECTION
CREWS INSIDE THE REACTORS.
INSTEAD, TEPCO SENT TWO ROBOTS.

III.

ONCE LANDSCAPED with greenery, the long, steep slope separating the upper and lower terraces of Fukushima Daiichi is now a moonscape of smooth concrete, designed to keep rainwater

from soaking into the contaminated ground. As the bus descended toward the ocean, we passed an area piled high with the sun-bleached trunks of dead pine trees. Only a few cherry trees had been spared the chainsaw.

Our first stop was an unremarkable windowless building situated on a hillside. Standing on top of it, I was eye-level with the roofs of the four damaged reactors. They were 19 stories tall, except for Unit 3, shortened by a hydrogen explosion that blew its top off. Crane booms used to erect new reactor coverings dangled high above them. The coverings prevent the spread of radioactive dust. Ultimately, they will provide a frame from which to suspend equipment, when TEPCO finally gets around to extracting the melted fuel.

Even under ordinary conditions, retrieving fuel rods from a nuclear reactor's core is a delicate procedure requiring the use of specialized machinery. The fuel rods are sealed inside a reactor pressure vessel (RPV), a 750-ton steel capsule filled with water lodged in the heart of the reactor.

Surrounding the RPV is the primary containment vessel (PCV), a massive, pear-shaped structure made of concrete up to 5 feet thick and lined with 5 inches of steel. The PCV, in turn, is embedded in a concrete honeycomb of utility rooms filled with a labyrinth of pipes, pumps, and other equipment.

The only part of the reactor visible to the eye is a thin outer layer of sheet metal and concrete.

Shucking our contaminated shoe covers, we boarded the bus and motored down a road at the base of the reactors. Units 1, 3, and 4 had suffered hydrogen explosions that looked dramatic in news footage. In reality the explosions blew apart only the reactors' thin outer layers,

leaving the massive PCVs mostly intact. At least that's the hope. Nobody can say for certain if the earthquake, hydrogen explosions, or some unknown event—a mysterious explosion was heard coming from deep inside Unit 2, for instance—had cracked the PCVs. Fatal radiation levels make it impossible to send inspection crews inside the reactors.

Instead, TEPCO sent two robots into the PCV of Unit 1 this past April to locate the melted fuel. One robot stopped working within three hours; the other persevered for four days. The best information TEPCO has received so far about the location of fuel debris came from a recent muon scan of Unit 1. The scan revealed a void inside the reactor pressure vessel, confirming the worst-case scenario: Molten fuel had burned clean through it and slumped to the bottom of the primary containment vessel. Fuel had probably melted through the RPVs in Units 2 and 3 as well. The likelihood of TEPCO meeting its 2021 deadline for the start of fuel-debris removal is, at best, remote. In the meantime, there's plenty of other decommissioning work to keep the company busy.

IV.

MY DOSIMETER beeped its first 20 μSv alert as the bus passed the Common Pool Building, where thousands of spent nuclear fuel assemblies sit submerged underwater. Nuclear reactors have to be refueled about every three years. At Fukushima Daiichi, hot spent fuel initially cools off in a pool on the top floor of the reactors before being transferred to the Common Pool Building. Unit 4 was offline at the time of the disaster, and therefore didn't melt down. In December 2014, TEPCO reached a major milestone when cranes hoisted the last fuel assembly from Unit 4's spent fuel pool. It plans to pluck the remaining spent fuel from the other reactors beginning in 2019.

The bus turned sharply onto

FUKUSHIMA



The destroyed Fukushima Daiichi nuclear power plant as seen from the bridge beside the Takigawa dam in Tomioka, about 7 miles southwest of the plant.

a steel-plated road that ran between the ocean and the four turbine buildings. Together, the buildings formed a featureless white wall longer than a Nimitz-class aircraft carrier. Tsunami-tossed wreckage was strewn against their foot: twisted ductwork, chunks of broken concrete pronged with rusty rebar, and large pieces of smashed equipment. We were perhaps 12 feet above sea level, the lowest point at the site, and an ideal vantage point from which to appreciate the immensity of both the reactor facilities and the tsunami that inundated them. Looking out to sea, it was terrifying to imagine a 50-foot tide of water rolling over the breakwaters and plowing into the bus.

Five years after the meltdowns, contaminated water continues to flow from the site into the ocean. Although TEPCO's most recent analysis of seawater shows a "nondetectable" level of cesium,

that level merely reflects a regulatory threshold. "Non-detectable doesn't mean the plant isn't leaking into the sea," says Ken Buesseler, a marine chemist with Woods Hole Oceanographic Institution. "In fact, TEPCO's data, like our own, shows continued elevated levels of cesium in ocean waters closest to the plant."

The bus braked in front of Unit 4. We got out to look at what TEPCO called the "seaside impermeable wall": 594 concrete-and-steel piles that run almost half a mile along the waterfront. It is the last line of defense between Fukushima Daiichi and the sea, though it is designed to protect the sea from the nuclear plant, not vice versa.

To understand the full scale of the water problem at Fukushima Daiichi, you have to go back to the disaster's early days. Under normal conditions, water circulates through the reactor facilities in a closed loop to cool the nuclear fuel and generate steam. That loop broke during the disaster, and TEPCO resorted to pouring seawater into the overheating reactors. The reactors and turbine buildings quickly began filling up with thousands of tons of highly contaminated seawater.

"A few more days and water would have overflowed the plant, which would've taken whatever they had and squared it in terms of a catastrophe," recalls John Raymond, founder of Kurion, a nuclear waste management company based in Irvine, California. "We heard that some of the men at the site would step in a puddle and get radiation burns immediately from it."

There are no longer skin-searing puddles of radioactive water on the ground at Fukushima Daiichi. But TEPCO is still circulating 320 metric tons of water per day into

the reactors to keep the melted fuel cool. An ad-hoc circulation loop now pumps contaminated water from the reactors to a purification system custom-built by Kurion that removes two of the worst radionuclides: cesium and strontium. Most of the water then goes back into the reactors, while some gets piped to the tank farm.

There are 1,000 tanks at Fukushima Daiichi, containing more than 700,000 metric tons of contaminated water, equivalent to nearly 300 Olympic-size swimming pools. TEPCO can't go on building tanks forever, nor can it discharge the water into the ocean. The water is contaminated with high levels of tritium, a radioisotope that can't be removed using conventional filtration technology. Even if TEPCO could eliminate the tritium overnight, it's doubtful the government would allow the company to dump potentially 1 million tons of "purified" Fukushima water into the ocean before the 2020 Tokyo Olympics; it would be a public relations nightmare. In the meantime, water tanks are sprouting up all over the site like colonies of toadstools after a rainstorm.

We boarded the bus and headed toward reactor Units 5 and 6. On the way, we stopped briefly at various well heads and filtration facilities designed to trap and treat hundreds of tons of groundwater that flows downhill toward the ocean every day—right beneath the crippled reactors. Some of the groundwater mixes with the highly contaminated water in the reactors and must be treated and pumped to the tank farm; some ends up leaking into the ocean, untreated. TEPCO has been testing an underground "ice wall" to divert the flow of groundwater around the reactor facilities, but there's no word on when the company will switch it on.

Located on high ground, Units 5 and 6 were untouched by the tsunami. But they lie directly in the path of the radioactive plume that ended up contaminating 3,500 square miles of land northwest of the plant. We passed dead pine trees scattered like orange toothpicks along the edge of a wooded area. Pine trees are particularly radiosensitive, and these had probably suffered the same fate as trees in Chernobyl's infamous Red Forest, a tract of pines killed by fallout. For the second and last time, my dosimeter beeped a 20 μSv alert. In two hours on-site, most of it riding on a bus, I'd received a radiation dose equivalent of at least four chest X-rays.

V.

THE FUKUSHIMA disaster had a chilling effect on the nuclear-power industry worldwide. Germany, for example, is phasing out of nuclear energy altogether. China suspended its rapidly expanding nuclear-energy program. And in Japan, where nuclear power supplied 30 percent of the country's energy, the entire reactor fleet was taken offline. But the nuclear chill has begun to warm up lately. Ten new reactors went online last year, the most since 1990. China now has 24 reactors under construction, with more on the books. Last August, Japan quietly restarted its first reactor since the disaster.

Ikuro Anzai, an owlish 75-year-old nuclear scientist from Kyoto, is skeptical of this development. He's

spent his career criticizing the incestuous relationship between government regulators and the nuclear industry that allowed companies like TEPCO to ignore safety warnings. In his view, Japan should follow Germany's example. Until that happens, the least the government could do is educate a skittish public about the health effects of radiation exposure. Anzai can't do much about the former, but few are better equipped, or motivated, to address the latter. He travels to Fukushima prefecture every month to measure radiation levels to reassure those who no longer trust the government—to say nothing about the nuclear industry—to protect their safety.

"The accident destroyed people's trust in the industry, in the government, and experts," Anzai said. "As a scientist, I want to make a sincere effort to stand beside victims and help minimize their exposure to radiation, and to restore trust in scientists."

On a drizzly afternoon, I met Anzai at the Torikawa Nursery

IN TWO HOURS ON-SITE, MOST OF IT RIDING ON A BUS, I'D RECEIVED A RADIATION DOSE EQUIVALENT OF AT LEAST FOUR CHEST X-RAYS.

School in Fukushima City, about 40 miles from Fukushima Daiichi. Although residents were never evacuated, radioactive hot spots in some parts of town still exceed the government's long-term decontamination goal of 0.23 $\mu\text{Sv}/\text{h}$. A gamma spectrometer hung on a strap over Anzai's shoulder as I followed him down winding lanes to an old Buddhist temple in the center of a residential neighborhood. Anzai knelt next to a swing set and held the spectrometer's sensor over a hole he'd made in the coarse sand.

"Zero point zero seven

microsieverts per hour," he announced. "It's the same as my office in Kyoto."

That was less than half the radiation levels Anzai found when he surveyed the same walking route two years ago, good news for the children who attended Torikawa Nursery School. Ever since the disaster they've been cooped up out of fear of being exposed to radiation. Now they could take their daily walk again.

"It's important for children to be able to touch the snow and step on the ice," the director of the nursery school, Miyoko Sato, told me. "But we still worry about the food the children eat." Food grown in Fukushima prefecture—famous for its produce in Japan—is closely monitored for radioactive contamination, but the school still sources its food from outside it. Understandably, many parents no longer trust authorities on any matter concerning radiation, which is ironic, because the food restrictions that the government put in place after the disaster were, in Anzai's view, one of the few things it did right.

As the cleanup of Fukushima prefecture and the decommissioning of the nuclear plant move forward, Anzai has one simple piece of advice for Japan's government and its nuclear industry, one that he's been repeating for more than four decades: "Don't hide, don't lie, and don't underestimate."

In many ways, rebuilding Fukushima is the easy part. Japan has recovered from far worse. Restoring public faith will be much more difficult because trust has no half-life. 

Reporting for this story was supported by a grant from the International Center for Journalists.

Manual

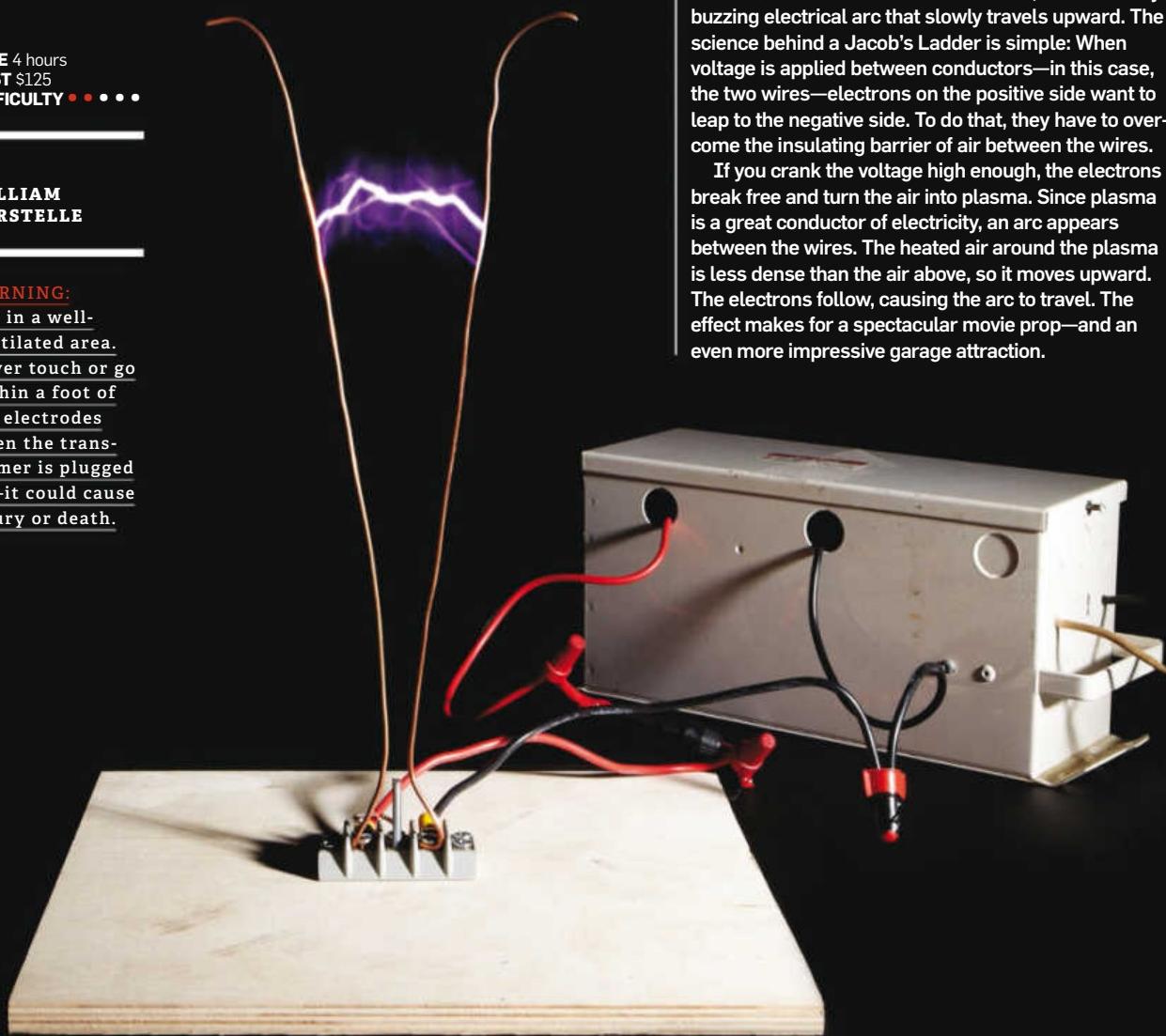
EDITED BY SOPHIE BUSHWICK

Unleash Your Inner Mad Scientist with a Jacob's Ladder

TIME 4 hours
COST \$125
DIFFICULTY • • • •

by
WILLIAM GURSTELLE

WARNING:
Use in a well-ventilated area.
Never touch or go within a foot of the electrodes when the transformer is plugged in—it could cause injury or death.



This year is the 85th anniversary of quite possibly the greatest monster movie ever made: the original *Frankenstein* with Boris Karloff. The classic film gave us now-common horror tropes such as mad scientists in ill-fitting lab coats, angry mobs with torches, and of course, the transformational power of high-voltage electricity.

Of the movie's many amazing machines (real and imagined), the Jacob's Ladder is perhaps the most iconic. It consists of two vertical wires, connected by a buzzing electrical arc that slowly travels upward. The science behind a Jacob's Ladder is simple: When voltage is applied between conductors—in this case, the two wires—electrons on the positive side want to leap to the negative side. To do that, they have to overcome the insulating barrier of air between the wires.

If you crank the voltage high enough, the electrons break free and turn the air into plasma. Since plasma is a great conductor of electricity, an arc appears between the wires. The heated air around the plasma is less dense than the air above, so it moves upward. The electrons follow, causing the arc to travel. The effect makes for a spectacular movie prop—and an even more impressive garage attraction.

TOOLS

- Screwdriver
- Soldering iron

MATERIALS

- 9,000- to 15,000-volt neon-sign transformer
- Three-position terminal strip
- No. 10 terminal screws
- Plywood board, 24-inch-by-12-inch-by-½-inch
- Two 14-inch-long No. 10 bare copper wires
- Two 1-megohm resistors
- 16-gauge insulated wire
- 1-inch-long No. 10 bolt with screw head cut off
- 22-quart clear polycarbonate container

INSTRUCTIONS

- 1 Make sure the transformer is unplugged before starting.
- 2 Attach the terminal strip to the center of the plywood with the No. 10 screws.
- 3 Attach the 10-gauge copper wires to the terminal strip, leaving one terminal between them. The wires will act as the electrodes.
- 4 Remove the screw from the terminal between the electrodes and replace it with the No. 10 headless bolt.
- 5 Position the wires vertically so they're about 1 centimeter apart at the end of the bolt, and then angle out to a maximum separation of 6 centimeters at the top.
- 6 Solder together the two resistors in series. Attach one end to one of the electrode terminals and the other to the bolt terminal.
- 7 Connect the positive transformer terminal to one electrode terminal and the negative transformer terminal to the other with 16-gauge wires.
- 8 Make sure the transformer case is grounded: If it has a grounding screw, connect the screw to the electrical plug's ground conductor.
- 9 For safety, cover the electrodes with the clear container.
- 10 Standing well clear of the electrodes, plug in the transformer. An arc will form at the bolt, travel up the electrodes, and reappear at the bottom.

ILLUSTRATION BY CLINT FORD

Watch a video of the Jacob's Ladder in action at popsci.com/itsalive.

Meet a Maker

MARCH/APRIL 2016

Weather Maestro

For nearly a decade, New Orleans organist and inventor David Rolston, better known as Quintrone, had harbored a particular dream: to build a synthesizer controlled by the weather. As a touring musician, he could never find the time. And then, in 2011, he was diagnosed with lymphoma.

"Theoretically, blind people could experience a sunset through sound."

While undergoing chemotherapy, Quintrone was stuck at home. "I spent much of the time on my front porch building prototypes," he says. "It brought me peace during a dark time." The resulting instrument, called the Weather Warlock, has sensors that detect sunlight, temperature, wind, and moisture. A custom circuit board transforms those weather patterns into droning noises.

Quintrone tuned the synth to a harmonious chord—E major—and used intervals that are

INVENTED INSTRUMENTS

Quintrone's other creations include the Spit Machine, a hand organ that uses saliva in its circuitry, and the Disco Light Machine, which uses a drum and lights to create music.

But his most notable invention is the Drum Buddy, a rotating, light-activated drum machine that creates different rhythms and sound effects. Artists Laurie Anderson and Sean Lennon, and the New Orleans Museum of Art, have purchased Drum Buddies.

The instrument was born of necessity, Quintrone says. "I wanted a synth that I could use to play and manipulate rhythms, while playing the organ with the other hand. That's not something you can walk into a store and buy."

"mathematically sympathetic": octaves, fifths, and major thirds. "The sounds the synth makes are harmonious and consonant, inspired by the healing state of mind that I was forced to be in," he says. He hopes the Weather Warlock will help others too.

"A lot of blind people cannot synchronize with cyclical changes in the day," Quintrone says. A live stream of the Weather Warlock's music could change that. To share it, he built the website weatherfortheblind.org.

by
AIMEE SWARTZ



Watch Quintrone perform with the Weather Warlock at popsci.com/quintrone.

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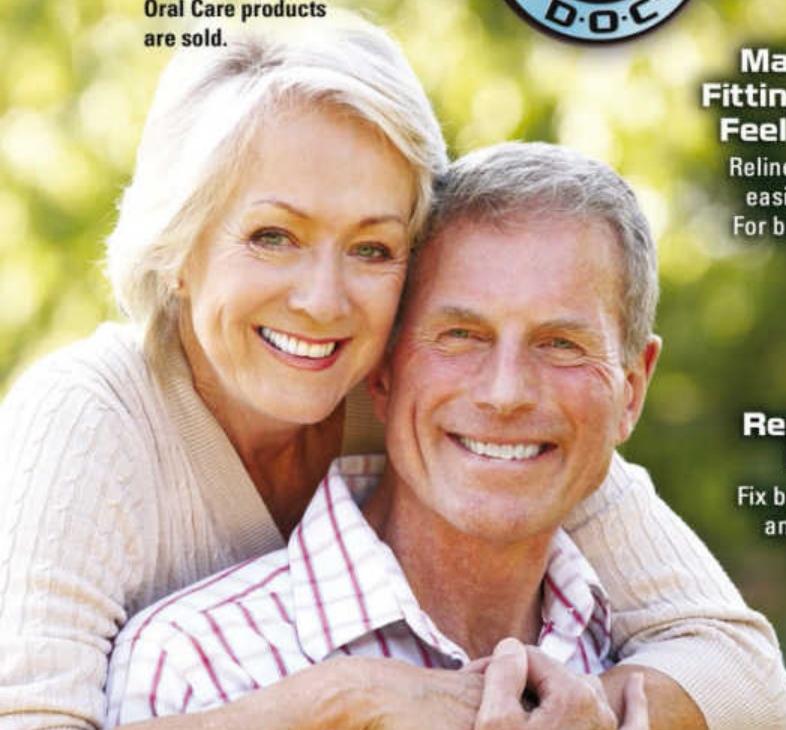
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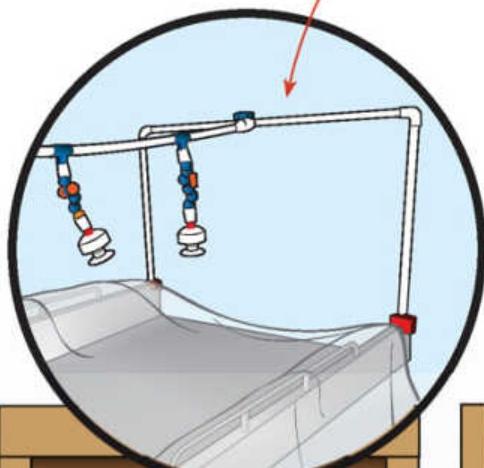
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Fix the World

Nursing Invention

While touring hospitals in Nicaragua, Jose Gomez-Marquez and Anna Young kept running across ingenious hacks, such as hand-cut cloth goggles to protect phototherapy patients' eyes and cereal boxes fashioned into IV patches. The medical-device designers

by
RACHEL NUWER



realized that Nicaraguan nurses were "stealth-making." Gomez-Marquez and Young began designing custom tool kits in order to help.

Back in the U.S., to better investigate and support nurses' making needs, they founded the MakerNurse program in 2013. The organization discovered that healthcare personnel were already modifying equipment to make it safer and more efficient. "To them, it's second nature," Young says. "They don't recognize their ingenuity as something that is worth talking about."

To foster that creativity, MakerNurse supplied several hospitals with portable prototyping carts equipped with tools, Velcro, and electronics. It also established the first medical makerspace in the U.S.: MakerHealth Space, at the University of Texas Medical Branch in Galveston.

The space contains equipment like 3-D printers, laser cutters, and sewing machines. Last September, 110 hospital

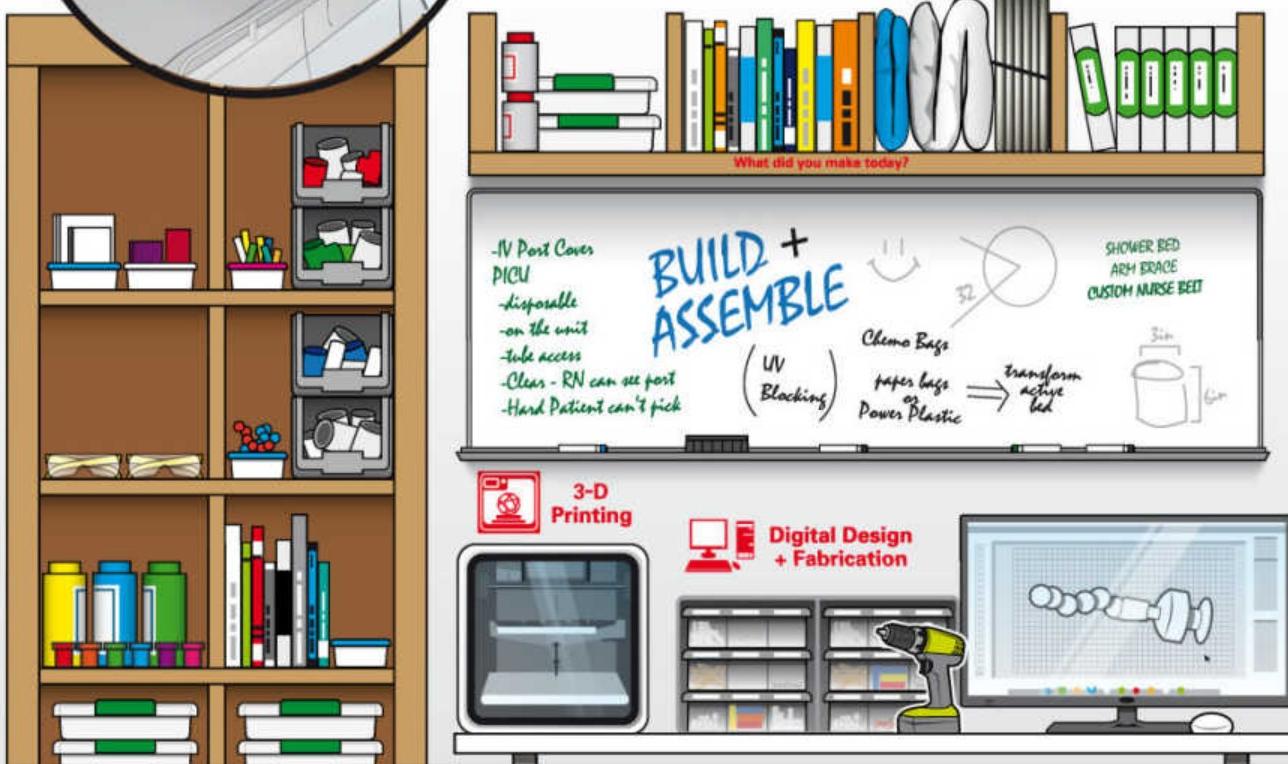
staff toured MakerHealth Space, and around 25 scheduled consultations with engineers who provide expert advice once a month. So far, their projects include a novel medication-delivery system and a knee-brace support.

"Ever since Florence Nightingale, nurses and healthcare workers have done things on the fly with materials designed for other purposes," says David Marshall, chief nursing and patient care services officer at UTMB. "Now they can develop those ideas near where they're actually delivering care."

DIY BURN BATH

When chemical-burn patients come to the ER, nurses must wash them by manually holding a showerhead for hours at a time. Jason Sheaffer, nurse manager for the Blocker Burn Unit at UTMB, turned to MakerHealth for a less onerous approach. Using

PVC pipes and 3-D-printed parts, he made a portable three-headed shower that can direct water over specific areas. "It seemed like an easy solution, but I could never get around to building it on my own," Sheaffer says. "Now if I have an idea, I can just run up to the makerspace and get the ball rolling."



There is something TERRIBLY WRONG with the Home Security Industry

Hi. Maybe you've been broken into before, or maybe you haven't. But if you ever decide to protect your home against unfortunate events like that, you're in for a shock. We don't want to scare you off of protecting your home, because honestly, it's really important that you do it. But we feel responsible for sharing these facts with you: Most alarm companies take advantage of people who want to feel safe. They offer you a "free" outdated alarm, but then require you to sign a long-term contract full of nasty fine print. It's pretty sickening really...but this isn't going to be all bad news. There is a better way to protect your home—get a SimpliSafe home security system. Our founder, a Harvard engineer, studied the alarm industry and found all kinds of problems with it. He designed SimpliSafe to fix them, so you can be safe, without having to spend a fortune or sign any contracts. SimpliSafe is wireless, you can order it online, and it's easy to install yourself—anyone can do it. It fits any home, apartment, or business. And it's more affordable, more reliable, and stronger than just about anything else out there.

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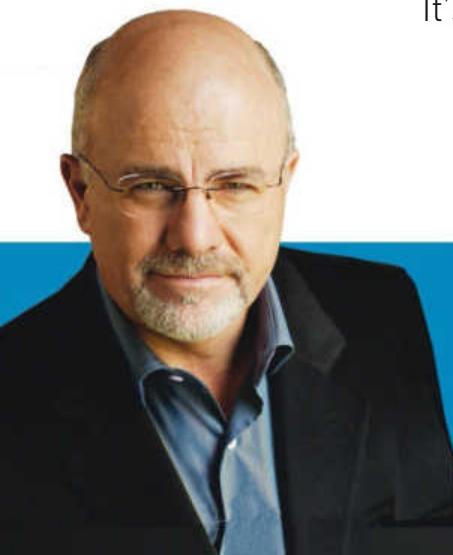
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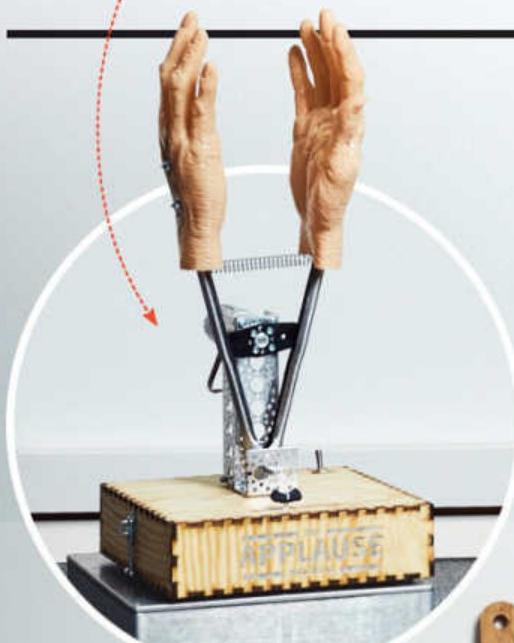


"Protecting your family is important, but don't ever sign a contract. Do it the right way with SimpliSafe."

—Dave Ramsey, financial expert & New York Times bestselling author



You Need an Applause Machine



Picture your hands after you've just watched an amazing performance. An evening spent clapping has probably left them red, tired, and blazing with pain. That's why I created a portable applause solution for the 21st-century human. With high-quality sound, speed control, and a custom laser-cut case, the **Applause Machine** will do your clapping for you.

To build it, I started with a pair of tongs from my kitchen. I attached a metal spring below the grippers, and put an oval-shaped DC motor between the arms. When the motor spins, it forces the tongs to open and close, creating a clapping motion.

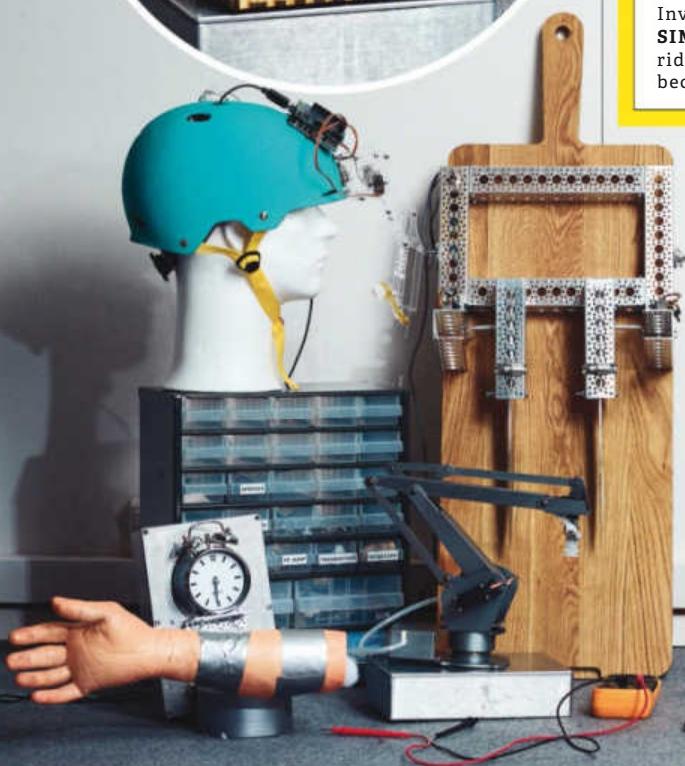
As for the machine's hands, I wanted to find a pair that would create the most realistic clapping sound possible. So I bought four different types of plastic hands from a party-supply store. After some experimentation, I decided that hollow hands made of rigid plastic created the best noise. I fastened them to the tongs' grippers with small bolts.

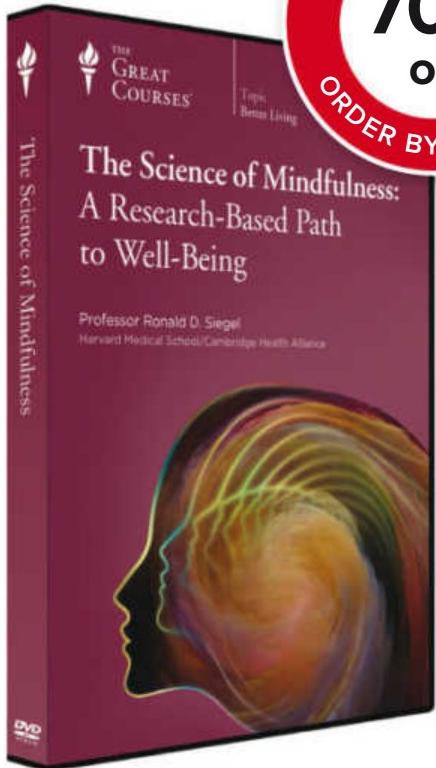
When it came to the machine's power

supply, I ran into trouble. The Applause Machine is controlled by an Arduino UNO: a tiny, inexpensive microcontroller that's great at reading sensors and managing hardware like motors. But it has only a 5-volt output, and the DC motor required 12 volts to run. To solve this problem, I inserted a MOSFET transistor—which allows you to control a high voltage with a low one—between the Arduino and the motor.

Last but not least, I added a slider to the front of the machine to control the speed. It can gradually increase from a snarky slow clap to a breakneck 330 claps per minute. After testing, it was evident that the Applause Machine is set to make the torturous practice of applauding a relic of days gone by.

Inventor and YouTuber
SIMONE GIERTZ builds
ridiculous contraptions—
because she can.





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Listen to Records with Your Teeth

You don't need a fancy machine, or even ears, to listen to old records. With science educator Sam Haynor's bone-conducting phonograph, you just need your teeth and some cheap everyday objects. Haynor places the record on a DIY turntable and then attaches a needle to a wooden skewer, which users bite. As the needle moves over grooves in the record, vibrations travel up the skewer and into the teeth and jaw. The brain interprets them as sound. Try it yourself, but be warned: Playing music through your skull can feel unsettling. "People give me that 'what are you doing to me?' look," Haynor says.

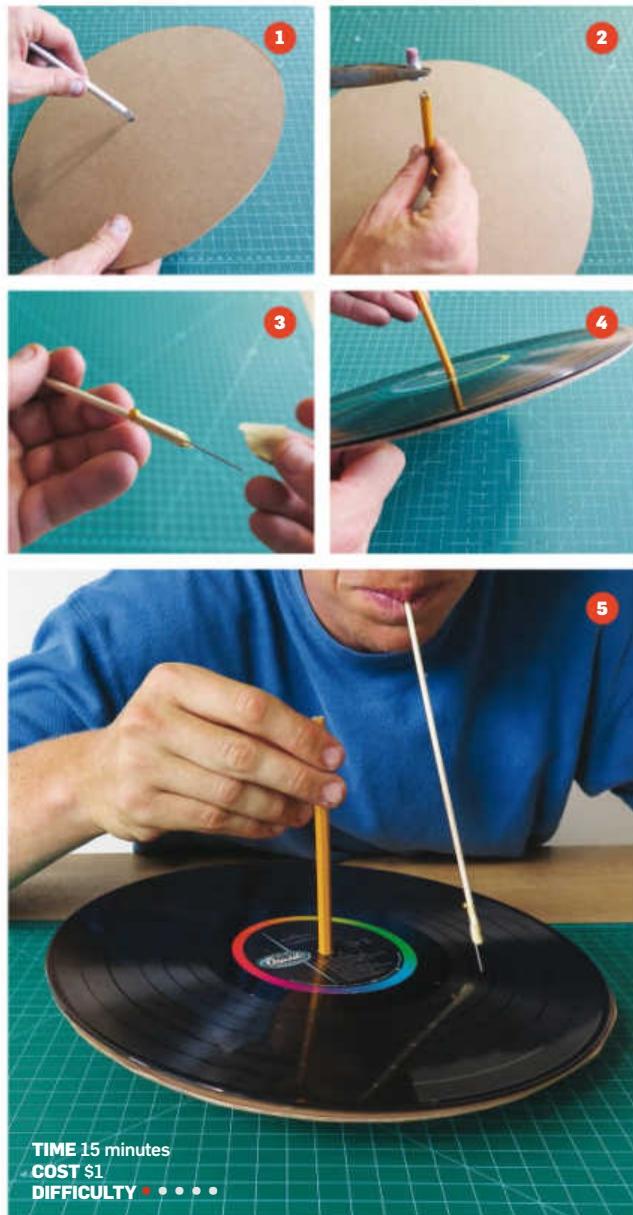
TOOLS+MATERIALS

- Inexpensive, disposable record
- Cardboard
- Sharpened pencil
- X-Acto knife
- Pliers
- Rubber bands
- Hot-glue gun
- Needle
- Shish-kebab stick
- Masking tape

INSTRUCTIONS

- 1 Trace the record on a sheet of cardboard and use an X-Acto knife to cut out the circle. Cut an X in its center.
- 2 Remove the pencil's metal eraser holder with pliers, and slide it through the X so an inch of the pointy end protrudes. Wrap rubber bands around the pencil as a stopper to keep it from sliding, and hot-glue it into place.
- 3 Secure the needle to the end of the shish-kebab stick with tape.
- 4 Thread the record onto the pencil, and place it on top of the cardboard circle. Set the pencil's point on a flat surface, and twist it to spin the record.
- 5 Bite the stick (don't touch it with your hands), then gently lower the needle onto the record so it catches a groove. Adjust the pressure and angle until you hear music in your head.

by
NICOLE LOU



TIME 15 minutes
COST \$1
DIFFICULTY • • • •

Bookmark

Onshape



Designing a high-quality 3-D model usually requires expensive, memory-hogging software. Onshape aims to change this by taking computer-aided design to the cloud. The modeling program can run as a Web page on your browser, or as an app on your mobile device. "Everyone on a product-design team now can work faster together," says Onshape co-founder and chairman Jon Hirschtick, "without having to copy software or CAD files."

Though the interface should feel familiar to veteran CAD users, Onshape has a library of videos to get people started, as well as a forum for learning about and suggesting new features.

Onshape offers all modeling and drafting tools for free, but unlimited storage costs \$100 per month.

by
JEREMY S. COOK

Do You Suffer From:

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- Joint Pain
- Back or Knee Pain
- Neuropathy
- Plantar Fasciitis
- Arthritis
- Diabetes
- Obesity
- Achilles Tendinitis
- Bunions
- Hammertoe
- Heel Spurs



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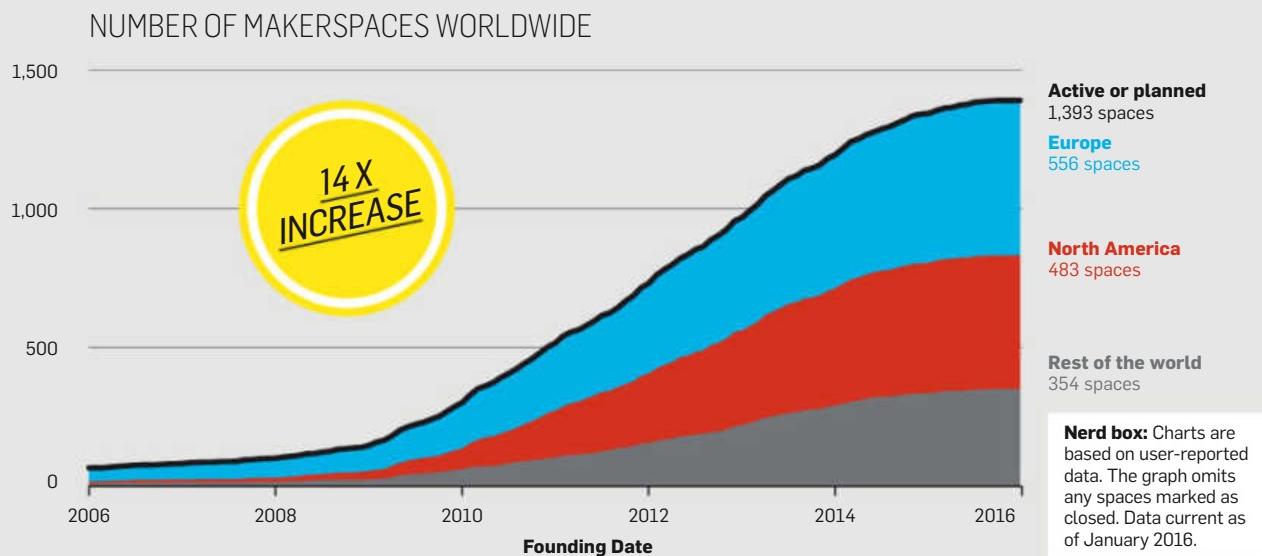
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ACCREDITED
BUSINESS

Rise of the Makerspace

SOURCES: HACKERSPACES.ORG; U.S. CENSUS BUREAU

by
NICOLE LOU

Over the past decade, makerspaces have exploded in popularity all over the globe—user-reported numbers show nearly 1,400 active spaces, 14 times as many as in 2006. Also called hackerspaces or innovation labs, these establishments act as communal workshops where makers can share ideas and tools. They can pop up anywhere, including in schools, libraries, and community centers. Different locations offer different resources,

ranging from 3-D printers to synthetic-biology kits.

Roughly half of American adults call themselves makers. "There's an increased awareness of how broad making can be and how inclusive it can be," says Steve Davee, director of education at the nonprofit Maker Ed. "But really, makerspaces in other forms have existed for a huge amount of time: We just called them woodshops, home-ec centers, model shops, and computer labs."

MAKING IN THE UNITED STATES

There are more than 400 U.S. sites for hacking and making, but these are the states where you're most likely to encounter them.

States with the most makerspaces

California	56
New York	31
Florida	24
Texas	20
Michigan	17

States with most makerspaces per person

North Dakota	5.4*
Wyoming	5.1
New Mexico	4.3
Montana	3.9
New Hampshire	3.8

*Spaces per 1 million residents

5-Minute Project

Pencil Plasma Cutter



Mechanical pencils aren't just for writing. Brian Jones, director of Colorado State University's Little Shop of Physics, a science outreach program, turned a stick of 5-millimeter graphite into a tiny plasma cutter. He attached the graphite and a piece of aluminum foil to four 9-volt batteries using alligator clips. When the graphite touches the foil, it completes the

WARNING: Wear goggles, work in a ventilated area, and be wary of hot wires and graphite, which can burn fingers and even catch on fire.

circuit, transmitting electricity. "The current has to go through the small area of the pencil lead," Jones says, "which gets really hot and vaporizes." The newly formed plasma can make precise cuts in the aluminum. It probably won't replace tearing—but it's certainly more dramatic.

by
NICOLE LOU

Chicago Doctor Invents Affordable Hearing Aid Outperforms Many Higher Priced Hearing Aids

Reported by J. Page

CHICAGO: A local board-certified Ear, Nose, and Throat (ENT) physician, Dr. S. Cherukuri, has shaken up the hearing aid industry with the invention of a medical-grade, affordable hearing aid. This revolutionary hearing aid is designed to help millions of people with hearing loss who cannot afford—or do not wish to pay—the much higher cost of traditional hearing aids.

**"Perhaps the best quality-to-price ratio in the hearing aid industry" – Dr. Babu,
Board-Certified ENT Physician**

Dr. Cherukuri knew untreated hearing loss could lead to depression, social isolation, anxiety, and symptoms consistent with Alzheimer's disease. **He didn't know why hearing aids were so expensive when the prices on so many consumer electronics like TVs, DVD players, cell phones, and digital cameras had fallen.**

Since Medicare and most private insurance plans do not cover the costs of hearing aids, which can cost between \$2,000-\$6,000 for a pair, many of the doctor's patients could not afford the expense. Dr. Cherukuri's goal was to find a solution that would help with the most common types of hearing loss at an affordable price, similar to the **"one-size-fits-most"** reading glasses available at drug stores.

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He evaluated numerous hearing devices and sound amplifiers, including those seen on television. Without fail, those were found to amplify bass/low frequencies (below 1000 Hz) and were not effective amplifying the frequencies related to the human voice.

Inspiration from a Surprising Source

The doctor's inspiration to defeat the powers-that-be that kept inexpensive hearing aids out of the hands of the public actually came from a cell phone he had just purchased. "I felt that if someone could develop an affordable device like an iPhone® for about \$200 that could do all sorts of things, I could create a hearing aid at a similar price."

Affordable Hearing Aid with Superb Performance

The high cost of hearing aids is a result of layers of middlemen and expensive unnecessary features. Dr. Cherukuri concluded that it would be possible to develop a medical-grade hearing aid without sacrificing the quality of components. The result is the **MDHearingAid PRO**, well under \$200 each when buying a pair. It has been declared to be the best low-cost hearing aid that amplifies the range of sounds associated with the human voice without overly amplifying background noise.

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The **MDHearingAid PRO** has been rigorously tested by leading ENT physicians and audiologists who have unanimously agreed that the **sound quality and output in many cases exceeds more expensive hearing aids.**

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—Dr. May, ENT physician

"They work so great, my mother says she hasn't heard this well in years, even with her \$2,000 digital! It was so great to see the joy on her face. She is 90 years young again." —Al P.

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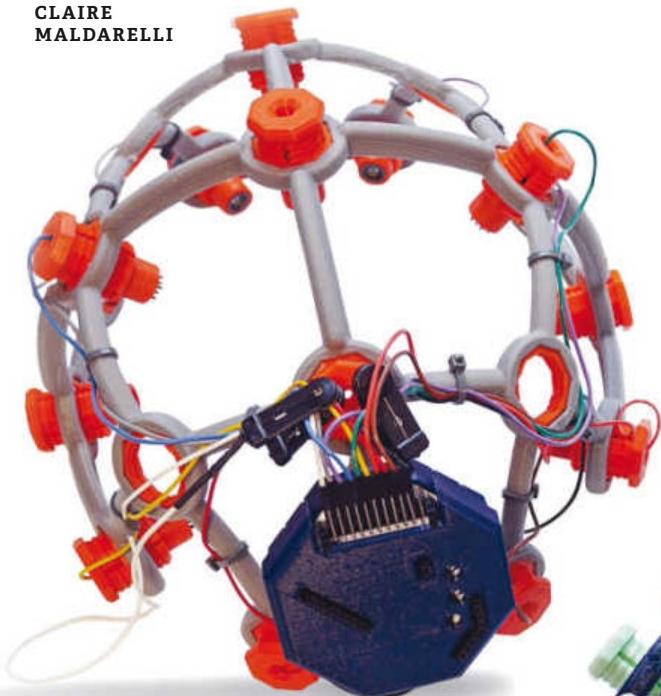
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by
CLAIRE MALDARELLI

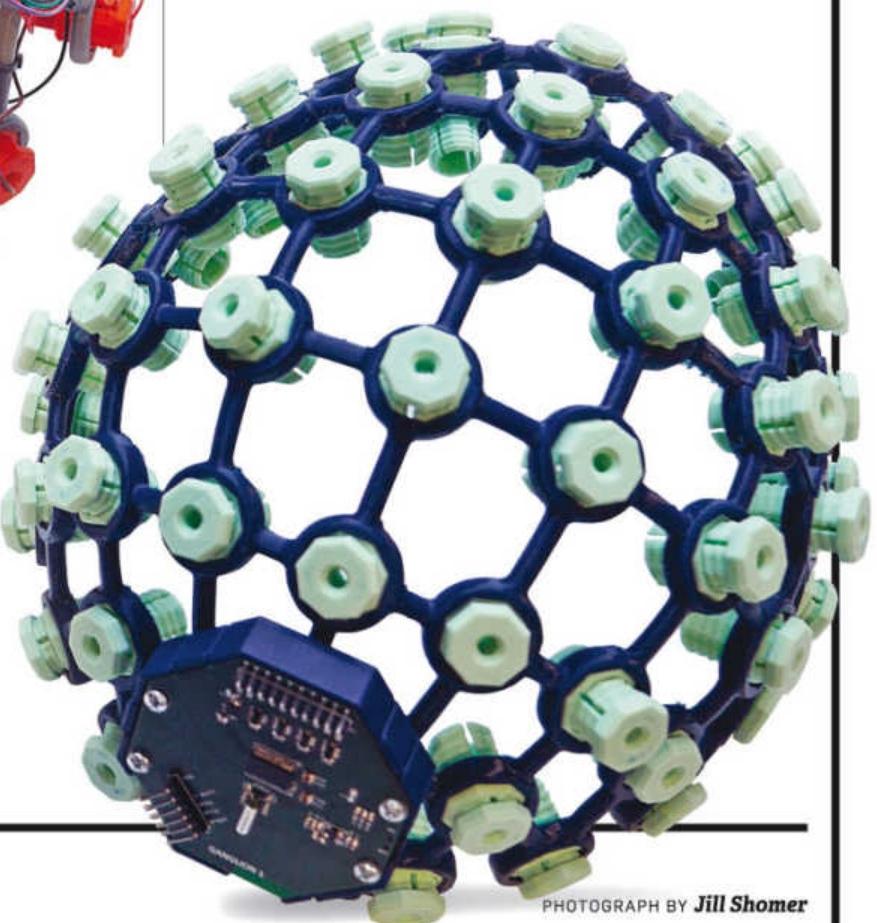


BRAINY IDEAS

- 1 In an attempt to better understand neurofeedback, Guillaume Dumas, a neuroscientist at the Institut Pasteur in Paris, created software that uses OpenBCI to turn brain waves into music.
- 2 At a hackathon organized by BCI Montreal, Canadian and Dutch participants combined OpenBCI with the Human-Human Interface, a DIY kit that

can send electrical impulses to a person's arm muscles. This let the hackers control the arms of strangers on the other side of the Atlantic Ocean.

- 3 Davide Valeriani and Ana Matran-Fernandez, doctorate students in brain-computer interfacing at the University of Essex, created an app that allows users to issue smartphone commands by winking.



Pressing buttons with your hands is a drag. With OpenBCI, an open-source brain-computer interface, you can use your mind to control smartphones, robots, and even your friends' limbs.

When DARPA funded research into a brain-computer interface, artist and engineer Joel Murphy and his former student Conor Russomanno built a working prototype. Then they decided to further refine the device in order to make the software and hardware cheap and accessible.

In 2014, the duo launched a successful crowdfunding campaign and eventually developed the Ultracortex, a \$399 3-D-printed electroencephalogram (EEG) headset, and the Ganglion, a \$99 circuit

board. The electrodes in the Ultracortex record your body's electrical signals, and the Ganglion transmits the signals to your computer. This allows you to control a mechanical device with your brain waves.

OpenBCI is intended as a DIY device. "We want it to essentially be a Lego kit that you get in the mail, which also just happens to be a brain-computer interface," says Russomanno. It could be used to control mechanical devices or computers with brainwaves or facial movement, or simply to watch one's own brain activity.

The products are available for preorder on the OpenBCI website. And because both hardware and software are open-source, you can 3-D print your own headset.

The Ultracortex (left) has 21 electrode holders. A new model (below) has 61 for more versatility.

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Manual

Biohacks

Grow a Thriving Bacterial Zoo

In the 1880s, microbiologist Sergei Winogradsky sealed pond mud in a clear tube. The column nourished a diverse mix of bacteria, which formed layers based on their energy sources: carbon, hydrogen, sulfur, or oxygen. This year, the American Museum of Natural History is revisiting the Winogradsky column by displaying a 6-foot-tall version through August. Can't visit? Gather some mud and create your own.

by
**STEPH
YIN**



MARCH/APRIL 2016

TOOLS+MATERIALS

- Buckets
- Shovel
- Large mixing bowl
- Mixing spoon
- $\frac{1}{4}$ -page of shredded newspaper
- 1 egg yolk
- Scissors
- 1 two-liter soda bottle with top cut off
- Plastic wrap
- Rubber bands

INSTRUCTIONS

- 1 Collect half a gallon of mud from a pond or stream, adding water until it has the consistency of a milkshake.
- 2 Mix a quarter of the mud with egg yolk and shredded newspaper. Spoon the mixture into the bottle. Keep filling the bottle with mud, and tap it periodically to remove air pockets.
- 3 Add an inch of pond water, leaving a little air at the top. Seal the bottle with plastic wrap and rubber bands, and place it near a window, out of direct sunlight.
- 4 Layers will develop over two months. Look for dark green, purple, and black sulfur-eating bacteria at the bottom; red, orange, brown, and purple carbon-eating ones in the middle; and green photosynthesizing microbes at the top.

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THIS MASK LETS YOU SMELL THE RAINBOW

What if you could smell fuchsia or taste the sound of a flute? For people who have synesthesia, these types of sensory associations happen every day. Zachary Howard, an aerospace engineer and an artist-in-residence at Autodesk, wanted to experience synesthesia himself. So he created a device that would turn colors into smells.

A sensor on Howard's finger detects colors. Based on the combination of red, green, and blue, three tubes of essential oil—one for each color—open into a mask to create a blended scent. The first thing Howard touched, a gray wall, yielded a nasty mix of all the smells. But he soon discovered he loved touching anything blue. "I'd get this amazing blast of lavender," he says.



by
**LYDIA
CHAIN**

1 The sensor detects the color of an object and sends it to a processor in the armband.

2 The armband holds an Intel Edison chip, which analyzes the color, breaks it into an RGB signal, and coordinates the scent release.

3 Each test tube holds a different scent. Howard used grapefruit for red, tea tree for green, and lavender for blue.

4 Two small fans blow over the mouths of the test tubes, picking up scent and carrying it to the wearer's nose.

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Q:

WHY DO SHOWER CURTAINS BILLOW INWARD?

Short answer Blame it on hot air, or swirling air, or something else.

A:

In 1938, Popular Science weighed in on this steamy mystery: "One inconvenience of bathtub showers has always been the tendency of the shower curtain to blow inward." Back then, we attributed this annoyance to the movement of air currents. Hot air produced by a shower has a tendency to rise. As it does, cold air from outside the tub moves in to replace it, pushing against the base of the curtain.

There's one problem with this theory: A curtain can billow inward during a cold shower too. What had we overlooked? It might be that water rushing from the showerhead sweeps a stream of air along with it, causing a drop in pressure surrounding the flow. This drop creates a space for air outside the shower to whoosh inward.

David Schmidt, a professor of mechanical engineering at the University of Massachusetts at Amherst, decided to test the cold-shower theory. In 2001, he created a computer model of a bathroom—complete with a showerhead, tub, and curtain rod—and found that shower water whipped the nearby air into "a sideways dust devil," with a pocket of low pressure in the eye of this mini storm. If a shower has enough pressure and a sufficiently flimsy curtain, the air outside pushes

the curtain inward toward the vortex.

That finding became state-of-the-art shower-curtain physics—until 2007. That's when physics-textbook author Peter Eastwell published a paper describing an unusual shower he'd experienced in an Australian motel room. He was able to adjust the curtain height, water temperature, and distance between the showerhead and curtain to find that, in fact, hot water does produce a greater "shower-curtain effect" than cold water. He also noticed if you set the stream of water close to, or far from, the curtain, the effect vanishes. That's consistent with Schmidt's findings of rushing water pulling air in its wake.

Now it's up to Schmidt to test his computer model in a real-world setting. Unfortunately, he's decided to throw in the towel. He just doesn't have the time to keep working on such a trivial question: "I'm done with the shower-curtain effect at this point," he says. "My wife jokes it will be the inscription on my tombstone: 'Here lies shower guy.'"



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ANSWERS BY **Daniel Engber**
ILLUSTRATIONS BY **Jason Schneider**

Have a burning question?
Email it to askanything@popsci.com or tweet it
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Q: **DOES GIVING BLOOD HARM YOUR IMMUNE SYSTEM?**

Short answer No.



A:

More than 9 million people donate blood every year in the United States, and for good reason. It saves lives and has no proven ill effects on the givers.

Research on these good Samaritans going back to the 1980s has found temporary drops in certain immune cells, such as circulating serum protein and antibodies. But science has never found a lasting impact.

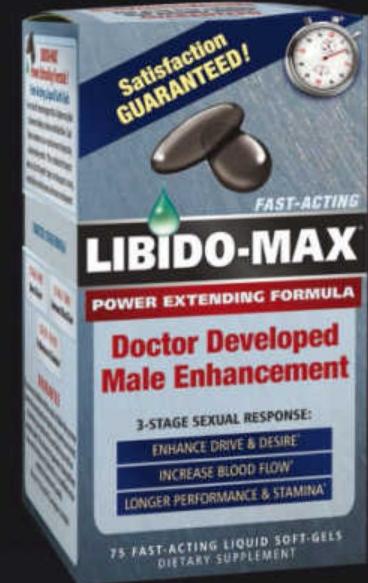
"Blood returns to normal in a few weeks," says Gustaf Edgren, a hematologist at Karolinska University Hospital in Sweden. "If the body needs more antibodies in the bloodstream, it will produce them extremely quickly." Edgren, who has studied close to 2 million blood donors, has also determined that they are no more likely than nondonors to develop cancer or die prematurely.

In fact, many donors believe that giving blood makes them healthier—a sentiment that might be a cultural vestige of medical bloodletting in the West. Though that fell out of favor a century ago, the act of shedding blood to boost health has seen an uptick since the 1980s with the advent of the

"If the body needs more antibodies, it will produce them extremely quickly."

so-called iron-store hypothesis. This posits that too much iron in the body can increase a person's risk for cancer and coronary heart disease. As evidence, adherents point out that women get cancer less often than men, and have lower rates of heart disease—at least until menopause—because they menstruate once a month, which lowers iron levels, and thus would offer natural protection.

Still, there's no credible evidence that donating blood improves well-being either, though lots of donors persist in believing they gain benefits from it. And that's OK. "Perception of health is a large fraction of being healthy," Edgren says. "So that's a good thing."



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Paul Fredrick

K-band false alarms driving you nuts?

The problem: Barraged by K-band false alarms lately? Seems like they're everywhere, and they hang *on and on*.

What changed? A new safety feature, the lane-change, or blind-spot, warning often uses K-band radar to "see" nearby cars.

V1 has the solution

The old problem of K-band door-openers was self-limiting. Buildings don't move. You're soon out of range. But a blind-spot system may tag along with you for miles. You're stuck, not knowing which car to maneuver away from.

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Mike Valentine
Radar Fanatic

MARCH/APRIL 2016



Q: DO BEARDS KEEP MEN WARM?

Short answer: Yes, unless they're caked in snow and ice.

A:

For centuries, bearded men have contended that a fuzzy face is nature's insulation. In a 1854 philosophical treatise on the topic, a Mr. Thomas S. Gowing contended that a beard's function is to protect "some of the most susceptible portions of our frame from cold."

Science has since proved him right. A 2012 study in China compared the skin of nearly 100 men's upper lips to their upper (and hairless) cheeks. Lips were, on average, 1 degree warmer than cheeks, suggesting a clean-shaven man is more likely to lose body heat from a susceptible bare ledge.

That mystery solved, some scientists now contend that beards might actually be too good at their intended jobs. Physiologist Michel Cabanac says there's a real danger (however slim) a beard will overheat the brain. To compensate, he theorizes, evolution came up with an adaptation: hereditary male-pattern baldness. Cabanac believes that less hair atop the cranium offers ventilation, which makes up for the heat-trapping chin pelt.

He calls this hypothesis "thermoregulatory compensation." To test it he studied 39 men over 10 years. He found that, sure enough, men with higher beard lines—shaved or not—had the most receding hairlines.

There's one other downside to a fuzz face: ice. Polar adventurer Eric Larsen, who treks through minus-50-degree weather, finds he needs a well-shorn chin. "I try to shave as much as possible," he says. "The benefits of having a beard are outweighed by the energy it takes to melt the ice that forms on it."

WHAT WOULD HAPPEN IF YOU

**ALTERNATELY HEATED AND COOLED WATER
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...the Hydrogen Bond Angle (HBA) in H₂O) AND CREATE A SPECIAL WATER that generated 100's of calls to The Washington Times and the Washington Post resulting in an Investigative Article Report: WP 1/27/92 "10,000 people/day travel to obtain this water that will cure anything!" However, the discovery was immediately debunked until a UCLA Medical School professor (doing independent Blood Flow Research) tested all types of water and after buying several E5 machines, said: "You can't argue with something you can measure! We can measure the ability of Blood (94% water) to go through a membrane into the cells to the extremities. Nothing is even close to your water! Do you realize you are the first person to change the properties of water with fantastic medical implications? Your Hydrogen Bond Angle is 10 degrees greater than ordinary water!"

However, In spite of the fact the results are measurable, a retired Chemistry faculty member from a Canadian University

tried to enrich himself by debunking the discovery at the expense of the University which resulted in 100's of letters and phone calls demonizing the man until they forced him to state: "They don't endorse him!". They also received complaints from our customers that included Sloan Kettering Oncologists and scientists at Lawrence Livermore including the top scientist at the Los Alamos Nuclear Lab (with so many degrees after his name he needs a fold-out calling card) who bought our E5 machine and called Jon Spokes, the Advertising Manager at The Washington Times National Weekly "I am embarrassed," he said, "to admit this, but John Ellis HAS changed the Hydrogen Bond Angle in water. I wish I owned his patents!"

Now, at 85 (it's a family effort) you can help our Living Water Environmental Foundation and get a 501 C3 Tax Deduction when you call 845 754-8696 to order a John Ellis Water Machine or John Ellis Water

With an Engineering Degree from Lafayette College that includes Steam Plant Design, John Ellis thought this would be impossible because the 104 degree Hydrogen Bond Angle (HBA) in ordinary water is only an AVERAGE that is constantly changing, forming ice with a 108 degree HBA for example. However, the "seed was planted" as a 16 year

old reading a book about the ancients in the Mellon Library at The Choate School that said: "Rapidly heating and cooling water produces mystical qualities". He never thought any more about it until Art Linkletter sent an M.D. to Hunza to see why they lived to advanced age in good health. He found that the people that lived the longest collected water during the day from pools of water in glaciers at the top of the mountains that later froze at night. However, the doctor was fooled into thinking this water was like "distilled water" which it isn't! Ordinary distilled water has a HBA of ONLY 101 DEGREES which produced the WORST measurable Blood Flow (above)! Although a 104 HBA is an AVERAGE, glacier water probably has more 108 (HBA) molecules even if it's heated/cooled only once daily. This gave John Ellis the idea to rapidly heat and cool water not once but 100's of times/gallon TO SEE IF IT WOULD INCREASE THE HBA AND INCREASE THE HEALTH BENEFITS EVEN MORE and it HAS... on any subject you can name! Like the Washington Post Investigative Article also says: "The curative power results from the movements of water between two metal tanks!" which is the result of our little countertop stainless steel machine! However, all claims are made for the WATER not a "machine device" adjusted at the factory. Thirteen Patents, 332 FDA Tests

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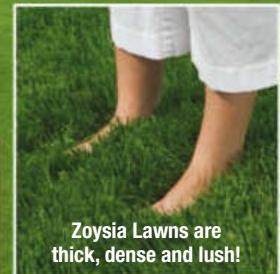
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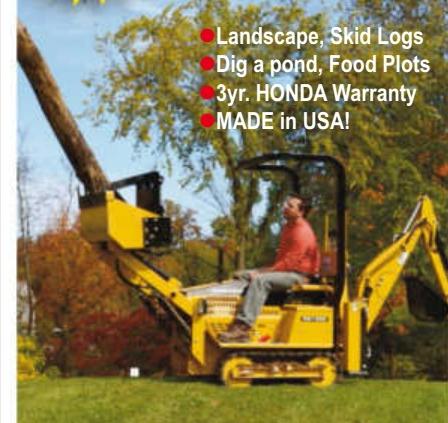
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Against a dusty and otherworldly landscape, science-fiction artist Stephan Martiniere posits that ships of a grand scale will be needed to create a living, working colony on Mars. Martiniere's craft evokes the space shuttle to spark nostalgia, which he mixes with considered conjecture about the technology needed to support those ships, and how their spaceports might be built efficiently into the landscape. Martiniere says when building environments like this one, 100 or 150 years out is a sweet spot: nothing is set in stone, but it's not so far away that artists can't imagine it. And the artists' ideas help people dream, he says: "Science needs to catch the imagination, and artists are free to do that—to convey the 'what if,' the beauty, and the magic."

by
KATIE
PEEK

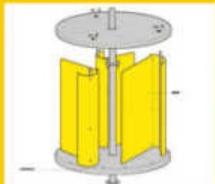
Dispatch from the Future is a series that imagines—through images and words—how humanity will live in the decades and centuries to come.

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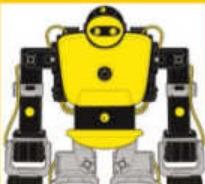
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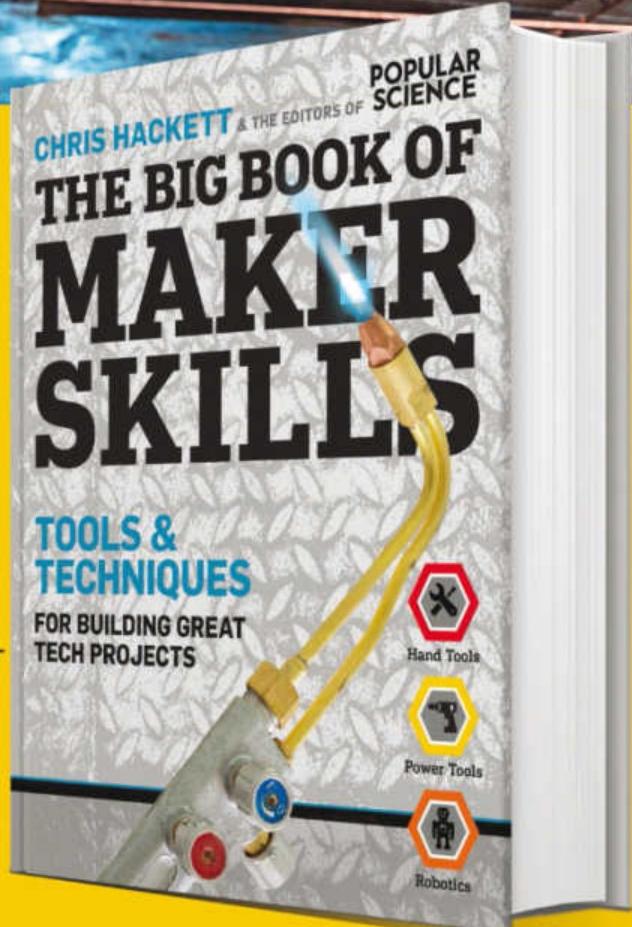


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